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October 1977

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ADVANCED SIGNALING/SUPERVISION AND ROUTING STUDY

RCA, Government Communications Systems

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ADVANCED SIGNALING/SUPERVISION AND ROUTING STUDY

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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The work which was accomplished under the ADSS (Advanced Signaling and Supervision) effort resulted in three major outputs, as well as some results based on off-line analysis.

a. A simulation model prepared in the GPSS language, was designed and tested. This model represents a multinode communications network where the nodes can be characterized to accommodate various switching services. In addition, the structure of the model allows modification of the traffic mix to reflect

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different distributions, as well as changes in internodal trunking facilities. This has been accomplished by organizing the program into four major modules, Traffic Generation, Network Simulator (describing connectivity), a Path Calculator, and Statistical Reporter.

The results of this model and its structure offer a flexible and useful tool for future switched network studies.

b. Three routing plans were tested with the use of the simulation. The two primary routing plans are Deterministic and Deterministic-Adaptive Routing Technique (DART); a modified version of the latter plan using a Calculated Path algorithm is slso considered. Each of the above routing plans were tested in the context of a hierarchical and a non-hierarchical structure.

c. Digital signaling and supervision based on protocols developed within the study were developed and used for establishing call/message flow and control.

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EVALUATION

The effort described in this report resulted in the development of a complex discrete event simulation of a multi-node, integrated communications system. The model was used to test the differences between deterministic and adaptive routing schemes in both hierarchical and non-hierarchical networks. In both cases the deterministic scheme proved better if one can live with the non-adaptability of this type of scheme. The model contained in the report was demonstrated effective in this kind of analysis. As written, it can easily be expanded for other studies planned under TPO 3. Portions of this model were used to support the ADP Telecommunications Program and Project 2022, Automated Digital Switching Techniques.

Daniel J. McAuliffe

DANIEL J. MCAULIFFE
Project Engineer

PREFACE

This study involved development of a communications network model, a series of algorithms and procedures for different message and call handling, design and test of a simulation program, and analysis of the results under various traffic loads. In addition, an analysis of projected processor call handling times and memory sizes was required for the various routing and signaling candidates and for the network architectures studied.

In addition to the authors, the following individuals assisted greatly in the effort: Kenneth Bodzioch, Thomas Russell, Irving Susskind, and Richard White, as well as short term assistance from other engineers and scientists at RCA.

The engineer at RADC (who gave both technical as well as contract direction) was Daniel J. McAuliffe.

1.0 ABSTRACT

The work which was accomplished under the ADSS (Advanced Signaling and Supervision) effort resulted in three major outputs, as well as some results based on off-line analysis.

a) A simulation model prepared in the GPSS language, was designed and tested. This model represents a multi-node communications network where the nodes can be characterized to accommodate various switching services. In addition, the structure of the model allows modification of the traffic mix to reflect different distributions, as well as changes in inter-nodal trunking facilities. This has been accomplished by organizing the program into four major modules, Traffic Generation, Network Simulator (describing connectivity), a Path Calculator, and Statistical Reporter.

   The results of this model and its structure offer a flexible and useful tool for future switched network studies.

b) Three routing plans were tested with the use of the simulation. The two primary routing plans are Deterministic and Deterministic-Adaptive Routing Technique (DART); a modified version of the latter plan using a Calculated Path algorithm is also considered. Each of the above routing plans were tested in the context of a hierarchical and a non-hierarchical structure.

c) Digital signaling and supervision based on protocols developed within the study were developed and used for establishing call/message flow and control.

d) A series of estimates were made for program and memory sizes, for various size circuit switches operating under the routing plans and signaling schemes. Quantitative sizing of each program varied for Deterministic and DART routing and whether in a hierarchical or non-hierarchical network structure. Call processing times were also investigated for the two primary routing plans under both hierarchical and non-hierarchical networks.

After an introduction in Section 2, a definition of the operational model in terms of the network selection and sizing, the routing plans and the state diagrams are discussed in Section 3. Section 3.1 describes how the hypothetical network was developed, and Section 3.2 describes from a set of rules, how each routing plan functions in the simulation to find paths through a hierarchical and non-hierarchical network. Section 3.3 describes the protocol of data transfer over a path once established.

In Section 4, a detailed description of each functional module of the simulation is presented.

Section 5 presents selected results obtained from the simulation pertaining to such parameters as number of calls completed and lost and delivery times, etc. Other pertinent results appear in Appendices I and II.

Section 6 presents two aspects of the simulated routing plans in a real world environment. Section 6.1 presents practical flow charts of the routing schemes and discusses the content of the various messages and Section 6.2 details memory requirements when the routing schemes are applied to practical switches.

In Section 7, some of the problems encountered in developing the simulation model are discussed as pointers to future users of the simulation technique for complex networks.

Finally, in Section 8 some suggestions are offered which should be considered for future study.

2.0 INTRODUCTION

2.1 STATEMENT OF THE PROBLEM

The report which follows addresses a simulation of a network which attempts to examine some routing doctrines and signaling and supervision in the context of those routing plans. Some special analysis of these routing/signaling plans, as tested by the simulation and also relating to "real world" considerations, has led to some recommendations on techniques for improving the routing and signaling/supervision.

The original concept, and the routing plans considered, derive from work published as RADC-TR-67-286, Advanced Digital Signaling and Supervision. During that program a network model concept was developed which included store-forward and circuit switched service. This was modified during this investigation to include a simplified packet concept using a subset of a store-forward algorithm.

2.2 APPROACH

In order to further address the ADSS effort, it is probably useful to state the objectives of a routing plan and associated signaling and supervision. A routing plan should be sufficiently robust that it demonstrates an ability to "find" available paths for a call or a message request based on preselected criteria. The criteria might be survivability, minimum connection time, cost objectives, etc. The signaling and supervision plan must exhibit at least three characteristics including: a) complete information to allow for completing the call/message attempt; b) relatively fast, and c) positive response or equivalent to guarantee accuracy of the signaling and supervising response information between an originating source and the destination, and the plan should also incorporate a robustness to accommodate error conditions.

A critical factor in the routing plan is in the method of determining the routes which might be attempted. This is independent of whether the plan is deterministic or an adaptive plan. The path selection or path calculating algorithm may be exercised a-priori and/or during the call attempt, but it must be integrated with the routing plan to support the routing plan criteria.

A modification of the model was prepared to accommodate a non-hierarchical network, while the original model which was also evaluated was based on a hierarchical structure. Briefly, the major differences include:

Hierarchical - most subscribers terminate on an access or tributary node. All calls which are destined for remote points (i.e., two or more inter-node links/trunks) must request routes from a regional node, which is the entry into the backbone/high density net.

Non-Hierarchical - all nodes have equal capability for tandem routing; thus call routing is established by each node.

The routing plans to be considered were Deterministic and DART. A third plan called Calculated Path was considered, but after considerable study, this was determined to be the route selection aglorithm, rather than a routing plan.

As a result, Calculated Path algorithm is used to establish routes for Deterministic and DART. The signaling plan involved a technique requiring an out-of-band trunk channel, using a quasi-message digital format. The signaling plan divides into two segments: the actual signaling/routing message to attempt to establish the calling/message trunk

request, and (reverse leg) supervisory messages to denote the successful or unsuccessful allocation of the trunk.

The resulting supervisory response varies depending on whether the call is a voice call or a data (packet or narrative/record) message. Two responses exist for the voice call; route/trunk available or a "busy" (node or trunk)/outage response. Alternate paths are attempted in the latter condition. The outage (node/trunk down) condition is considered a long term condition and essentially reflects a network status message, which modifies the routing selection strategy. Data traffic is handled differently than voice calls. Where a busy/outage supervisory response is sensed by the originating node, data (packet or record message) is sent forward in the network to a responsible data node, which queues it up for future attempts at delivery.

Certain assumptions and simplifications were made to facilitate attaining useful runs. These include the assumptions made for the model, the actual conditions in the network, and the characteristics of the node and its associated processing functions.

In brief terms, the assumptions were:

1. Nodal processing times were quantified at a fixed level.

2. Internodal trunks were sized arbitrarily to develop trends from test runs. The trunk sizing was "tuned" as experience was developed on the network model and imposed traffic.

3. Network and model stability was determined on an empirical basis. This reflected a compromise between statistics which apparently showed stability after various test runs and excessively long runs or extensive model analysis.

4. Analysis of the impact of the routing and signaling plans on program size and call handling times were based on flow charts, and extrapolantions, from the ICMS Program described in RADC-TR-72-27.

In order to expand on these, it is desirable to examine the considerations or environment which governed the assumptions.

The primary emphasis of the simulation was to investigate performance within the network; this meant that the nodes were to be made as "transparent" as possible. Since nodal delays in call message handling vary as the traffic load, queues, configurations of hardware and software, etc., the quantification of cross-office delay was fixed rather than develop a lengthy investigation of the probabilistic performance of a node. The model is sufficiently flexible so that a rigorous nodal delay model can be incorporated if desired.

The original sizing of the trunks created conditions where a large number of calls were blocked. Therefore, by examination of the test runs and the derived blocking performance, it became apparent that the trunk sizing was inadequate.

Recourse to standard telephone traffic analysis and careful review of the statistics gathered in these runs allowed fine tuning of the trunk sizing, so that:

a) Apparent network stability was achieved without long CPU runs;

b) call blocking statistics were at acceptable levels.

The question of network model performance under an imposed traffic load introduces the need to achieve a stable situation. From the pragmatic viewpoint, it was decided to run the model under well defined conditions to achieve a point where the model apparently has reached steady-state (or near) conditions. As can be seen, stability is a function which is related to many factors: (a) "real world" factors - trunk blocking, nodal call (message handling) delays, queue lengths, available routes; (b) simulation related factors - length of the run, correlation of the collected statistics, intensity and distributions of traffic introduced at various points in the run, and various model characteristics.

The analysis of the memory sizing and call handling functions was based on circuit switch call handling program flow developed under the ICMS Program. This also related timing to a specific controller. However, the routing and signaling supervision as considered in this study were introduced as additional functions. The estimates for these functions were for the Deterministic and the DART plans, for the hierarchical and non-hierarchical networks. It must be noted that the estimates of memory size do not necessarily require that all these functions be in working core; in particular, the adaptive routing path algorithms within DART could be overlaid from mass storage only when required.

Finally, the use of standardized simulation language and structure (originally Flowsim, and finally GPSS) was an important factor in allowing concentration on the model and

real world factors. However, it should be noted that there were discrepancies between the user manuals and the level of program issue on the machines used. The user should consider these factors when attempting to use the GPSS package in conjunction with the ADSS Program.

3.0 DEFINITION OF OPERATIONAL MODEL

3.1 NETWORK SELECTION AND SIZING

3.1.1 INTRODUCTION

The selection of the original network as presented in the proposal was arbitrary and selected as a point of departure.

As the program developed and trial runs of the simulation were made, adjustments in trunk capacities, node capacities, and connectivity were seen to be necessary in order to prove that the simulation was indeed functioning correctly with respect to the various functions of trunk busy, node busy, and pre-emption.

The final network was reached through a heuristic analysis of traffic since the original runs of the simulation showed the capacity to be inadequate. This analysis will be discussed later in this section.

The following sections describe how the network was developed, leading to the ultimate simulated network and the factors affecting the changes from one to the other.

The organization of the program requires a brief discussion at this point. The major program modules and their functions are:

a) Traffic Generator (TRGEN) - Translates the input traffic statistics to a series of transactions reflecting voice and data (packet or message) to be handled by the network.

b) Path Calculator (PCALC) - Depending upon the routing plan, a path is determined for the call on each transaction by the calculated path module, which then allows the Traffic Generator to release

the transaction to the simulated network.

c) Network Simulator (NETSIM) - This processes and follows the actual transaction as it precedes through the network, i.e., it involves the signaling and supervision, as well as connect/disconnect, channel selection, and information movement.

d) Statistical Reporter - This module collects and tabulates all the data representing the network performance, as represented by snapshots of the message (voice or data) status and history. Thus, delays, length in queue, message types, etc. are recorded and tabulated.

3.1.2 BASIC NETWORK A

The basic network is the one presented in the proposal and shown here in Figure 3-1.

No trunk capacities were assigned at this point but high density trunks designated as the super-net (back-bone) were assigned as the main route.

Packet and message switching nodes were arbitrarily assigned. The types of nodes, tributary, regional, etc. are recognizable from the key.

3.1.3 NETWORK B (MORE CONNECTIVITY THAN NETWORK A)

Network B, shown in Figure 3-2, assigns capacities to the trunks between nodes. These values were arbitrarily assigned, and as will be seen later, proved to be inadequate in simulation runs. The conclusion reached here shows the value of simulation of a complex network.

Since packet switched traffic was of considerable interest in the simulation, additional nodes were assigned a packet switching capability.

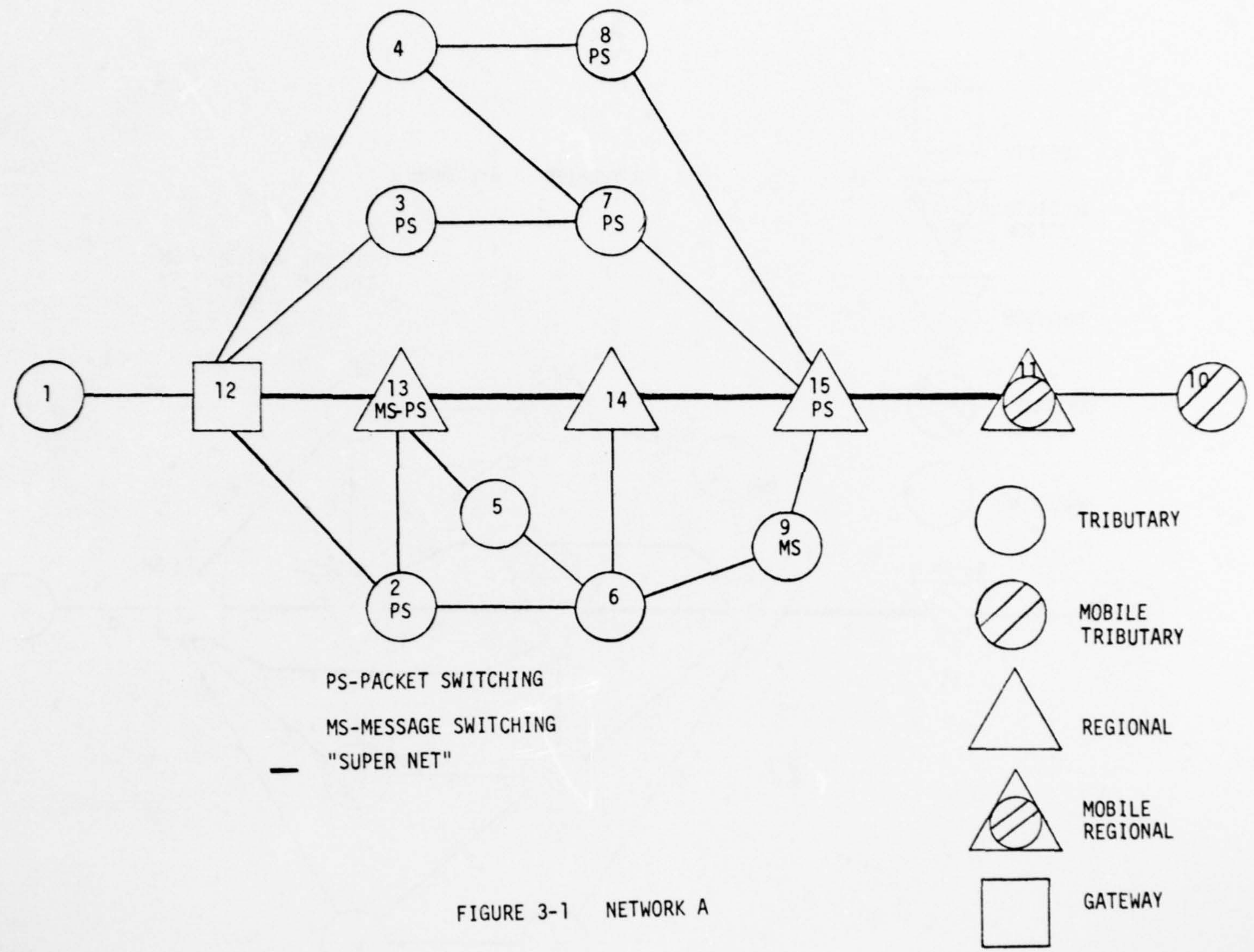
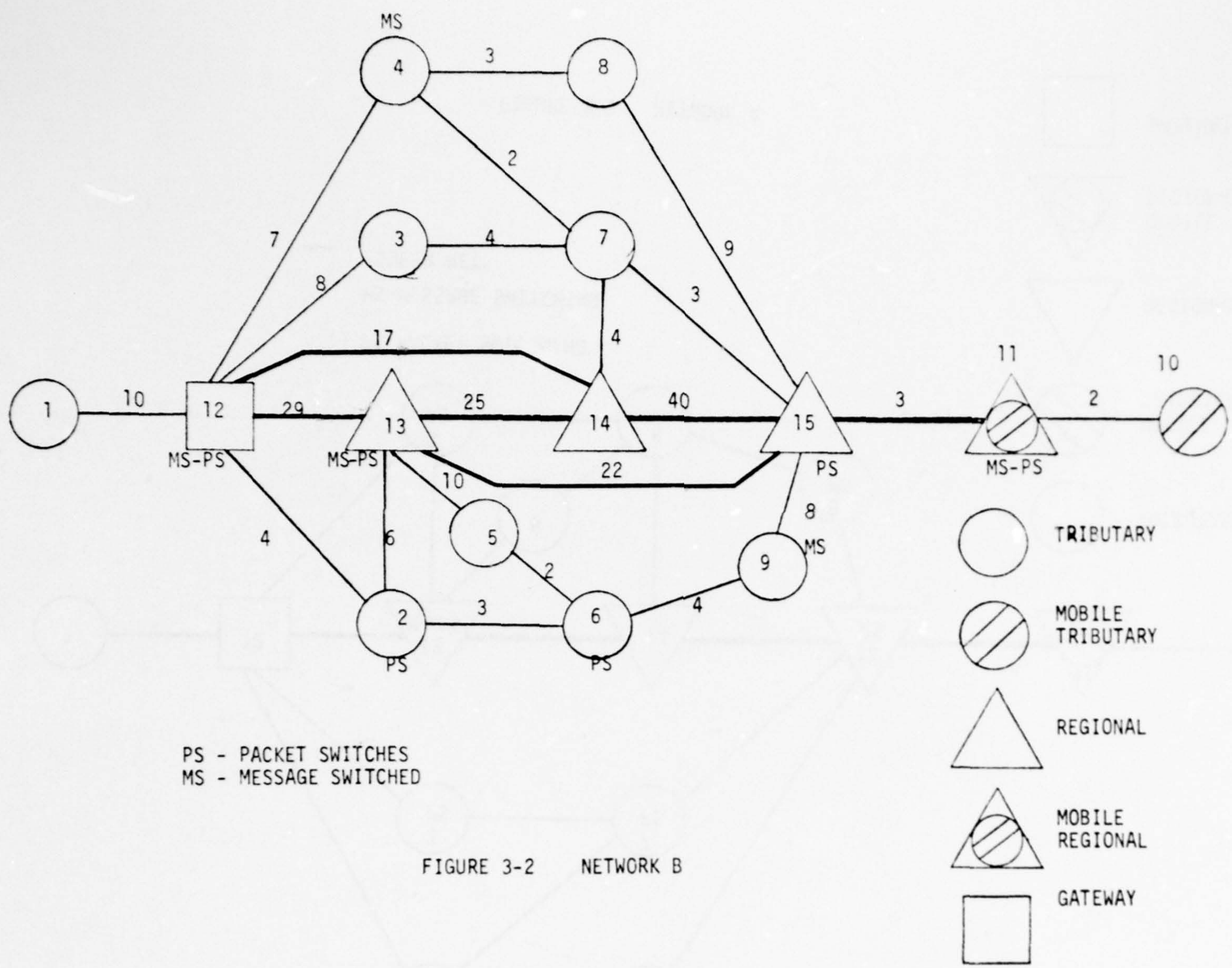


FIGURE 3-1 NETWORK A



PS - PACKET SWITCHES
MS - MESSAGE SWITCHED

FIGURE 3-2 NETWORK B

This network was the first network for which a connectivity matrix was prepared for the simulation program.

3.1.4 NETWORK C (MODIFICATIONS OF MODEL)

Several alterations to Network B were made to facilitate the testing of the NETSIM program as shown in Figure 3-3, including more adequate trunk sizing.

It was determined at this point that the voice and data traffic flowing in the network represented independent areas of interest and it was, therefore, decided to create separate pseudo-channels for handling the two types. The number of data channels is the same as that shown in Network B, but the number of voice channels were assigned to reflect the longer call duration for voice calls, and it will be noticed that in most cases the number of voice channels exceeds the number of data channels.

In addition to the assignment of voice channels, separate signaling and supervision channels were assigned between nodes, one for voice calls and one for data. Finally, and in order to simplify the testing of the NETSIM program, the link between nodes 4 and 12 was eliminated.

In order to test that the network responded correctly to such functions as node busy, trunks busy and pre-empt, the link capacity between nodes 3 and 12 and between 2 and 12 were reduced to 1. This ensured that the trunk and node busy conditions would be encountered by the test message.

3.1.5 NETWORK D (CHANGE IN NODE CAPACITY)

The basic difference between Network D shown in Figure 3-4 and Network C is noted in Node 9 where the nodal capacity was reduced to 1. This change was also made to facilitate testing of the NETSIM program and in particular, the

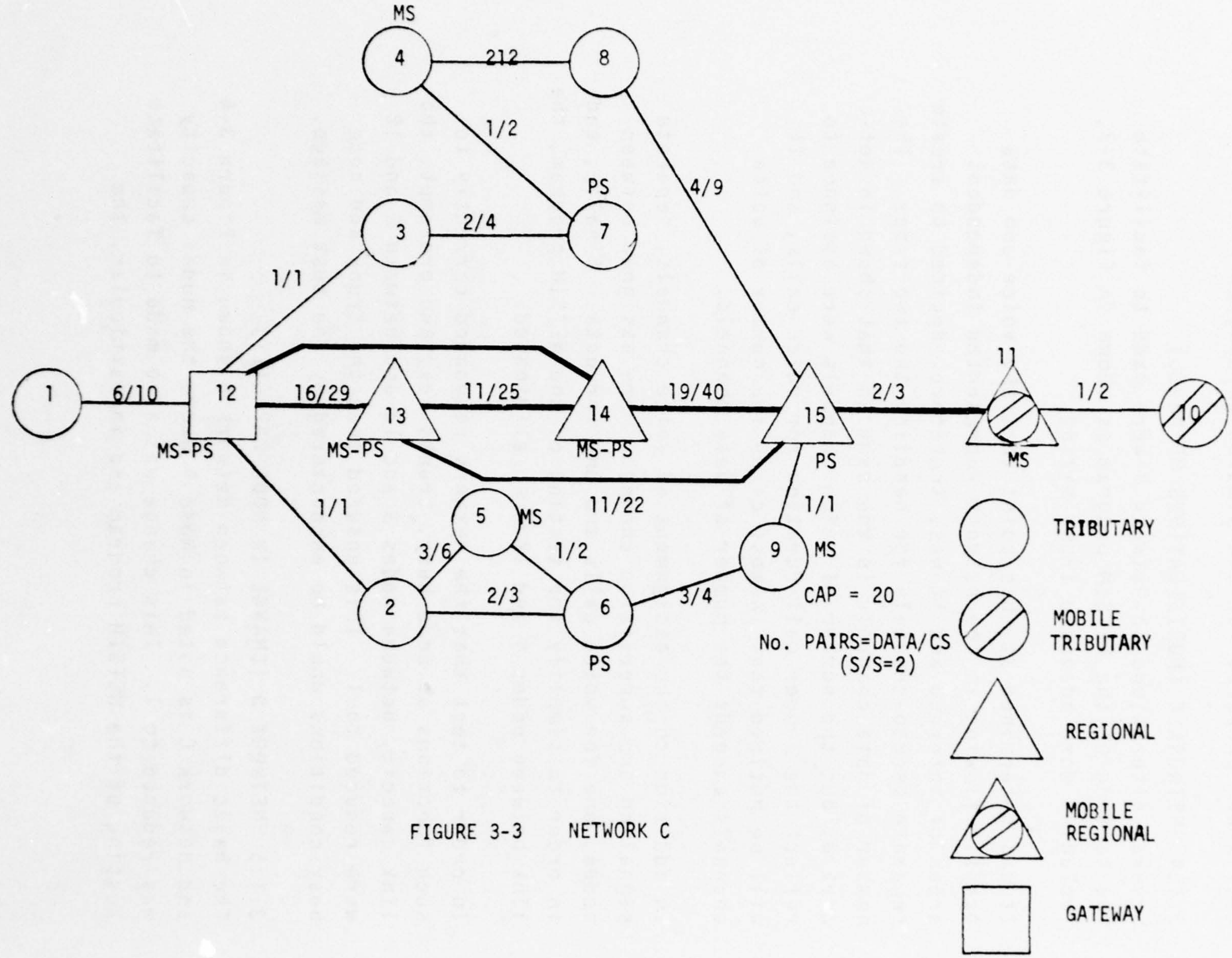


FIGURE 3-3 NETWORK C

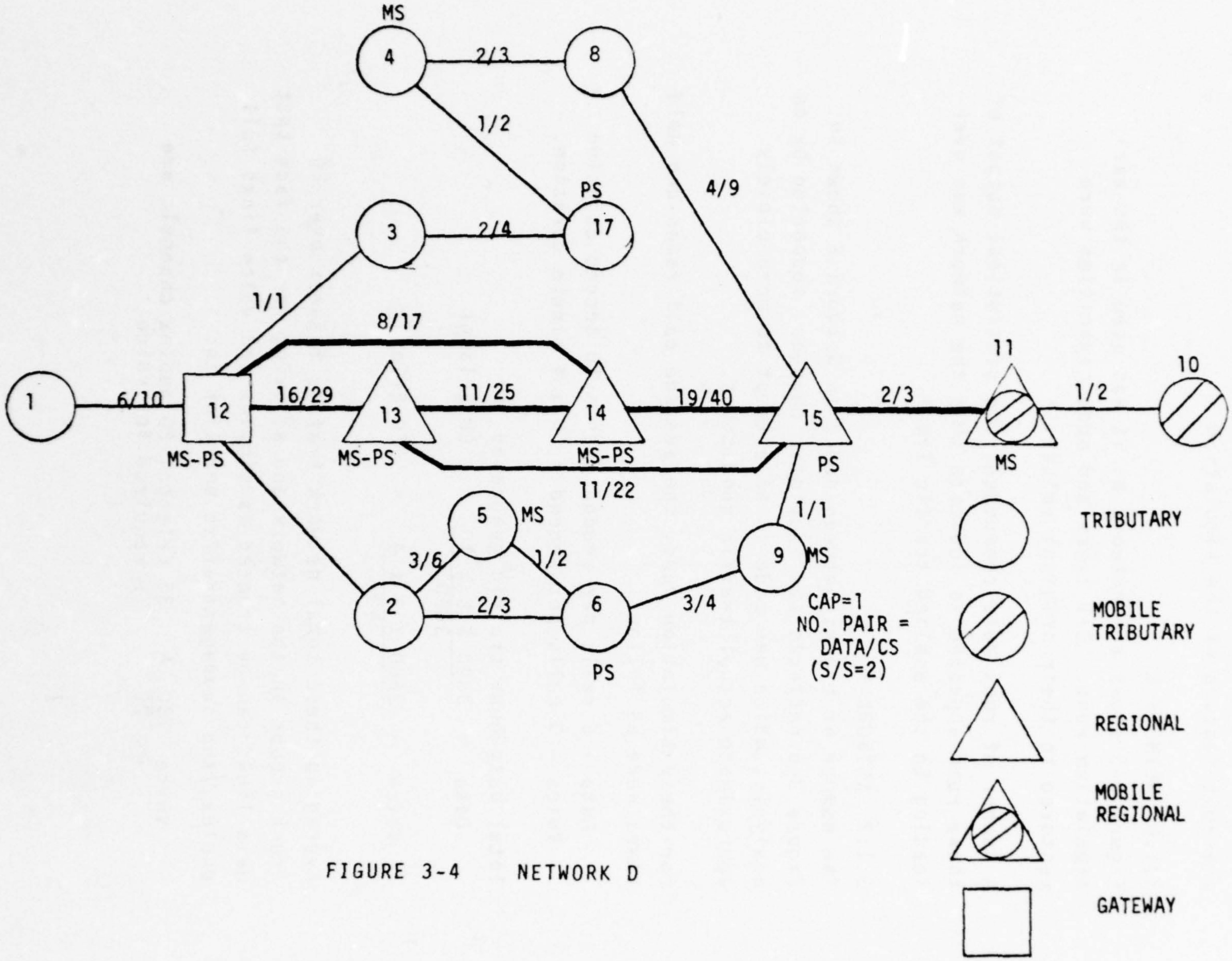


FIGURE 3-4 NETWORK D

pre-empt feature of the simulation.

3.1.6 NETWORK E

Figure 3-5 shows the network as it was used in the early simulation runs. All links and node capacities were restored to their original values.

A number of runs were conducted; the statistical output of these runs appeared to indicate that the network was overloading to the applied traffic level.

3.1.7 NETWORK F

The number of trunks between nodes in Network F shown in Figure 3-6 reflects the heuristic changes, supported by an analysis, which was made in an attempt to more closely approximate actual traffic conditions.

For these simulation runs, the average call rates and hold times were as follows:

Data - 6 calls per second with a 10 second duration
Voice - 3 calls per second with a 4 minute duration.

Total busy hour traffic generated is:

$$\text{Data} = \frac{3600 \times 6 \times 10}{3600} = 60 \text{ Erlangs}$$

$$\text{Voice} = \frac{3600 \times 3 \times 4}{60} = 720 \text{ Erlangs}$$

Averaging these total network traffic figures over 20 trunk groups in the network and allowing for the fact that data links can be treated as simplex and voice links full duplex, the average traffic per link is:

$\text{Voice} \ \frac{720}{20} =$ 36 Erlangs, 20 duplex channels are required for voice.

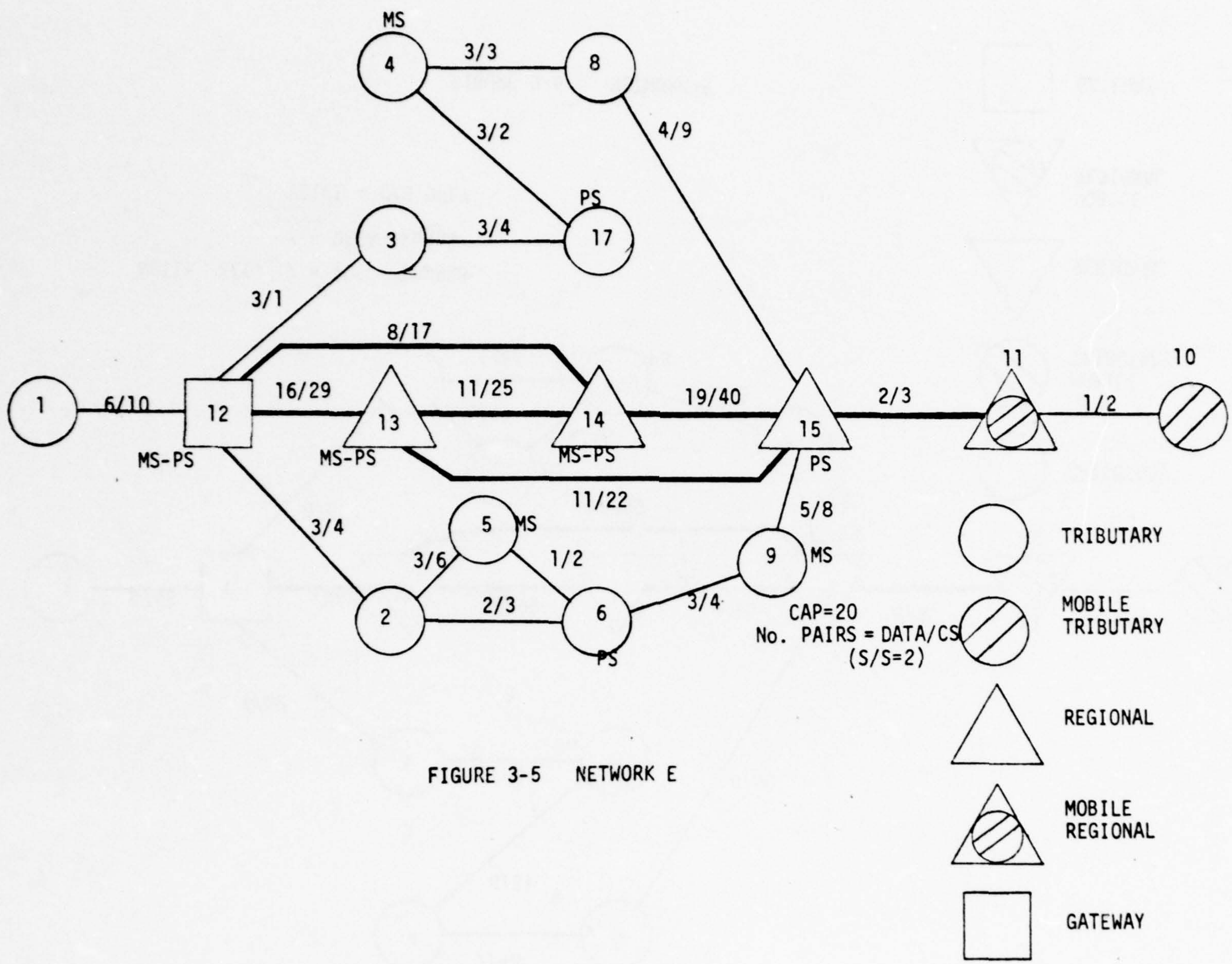


FIGURE 3-5 NETWORK E

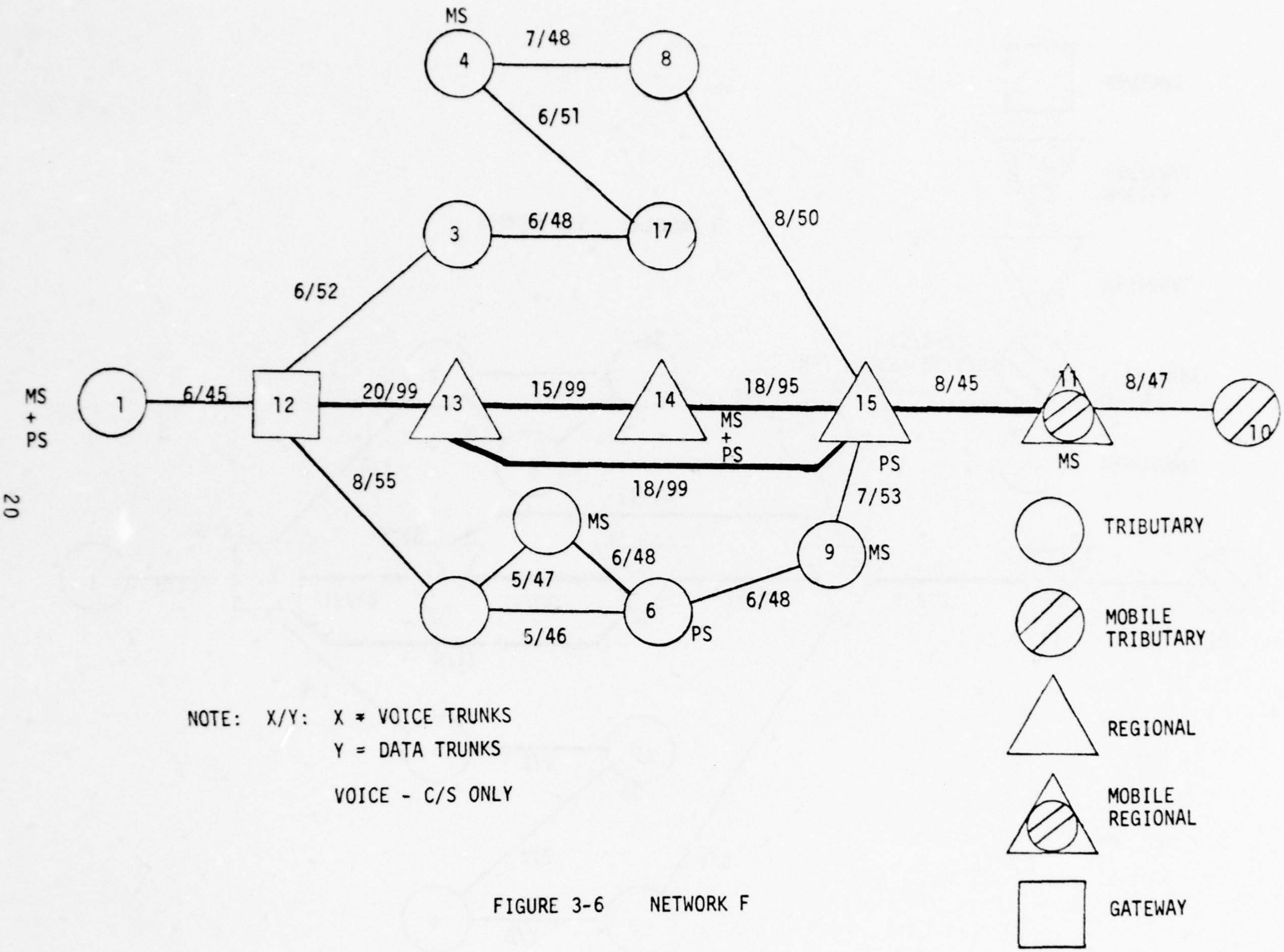


FIGURE 3-6 NETWORK F

Data $\frac{60}{40}$ = 1.5 Erlangs, 40 (simplex) channels are required for data.

Applying Erlang "B" and a blocking probability P_B = .001 the average number of trunks required is:

Data	=	6 Channels
Voice	=	48 Channels

Applying these values to Network F gave the values as shown and provided the network on which the ultimate simulation runs were made.

3.2 ROUTING PLANS

3.2.1 INTRODUCTION

The hypothetical network defined in Section 3.1 was the basis for determining the mechanization of the routing schemes to be simulated. For the purpose of simulation, the network was assumed to be both hierarchical and non-hierarchical, these items defining the inter-relationships and responsibilities of the nodes. The following section describes how each of the routing schemes were defined for the purpose of the simulation. The definition consisted of: establishing the routing rules whereby a path is determined through the network, and in formulating the protocol by which information is transferred over the established path. Both of these functions are essential inputs to the simulation.

Two basic routing schemes were simulated as follows:

a) Deterministic

b) DART (Deterministic Adaptive Routing Technique).

Within the structure of the DART method is an algorithm which calculates a path through the network and is referred to in the simulation as PCALC.

Since the simulated network is universal, i.e. it provides for circuit switching, packet switching and message switching, the protocols involved within a given routing scheme must vary according to the type of information being handled. This variation comes about since only selected nodes have message and packet switching capability. When over-laid on a hierarchical and non-hierarchical network structure it is possible to define a total of eight combinations of routing rules which are summarized in Figures 3-7 through 3-14.

Each of these figures has a hypothetical network for descriptive purposes which is a subset of the full network previously described.

Abbreviations used throughout these figures are as follows:

- OT - Originating Tributary - a node at which a call originates.
- DT - Destination Tributary - a node at which a call terminates.
- RON - Responsible Originating Node - a node used only in packet or message switching being the nearest node to an originating data subscriber which has message switching capability.
- RDN - Responsible Destination Node - a node used only in packet or message switching being the nearest node to a terminating data subscriber which has message switching capability.
- PNR - Packet Narrative Record - a collective term for packet and message switching.

3.2.2 DETERMINISTIC

3.2.2.1 Circuit Switched Hierarchical

The routing rules for the deterministic routinq scheme for circuit switched messages in a hierarchical network are shown in Figure 3-7.

Actual routes in this method are stored in the Regional Node and are passed to the OT on request. The route passed to the OT consists of the primary and the alternate route.

Each succeeding node through which a call passes determines the availability of the specified route and failure of a route request either because of busy trunks or node blockage results in the message reverting to the OT for an alternate route.

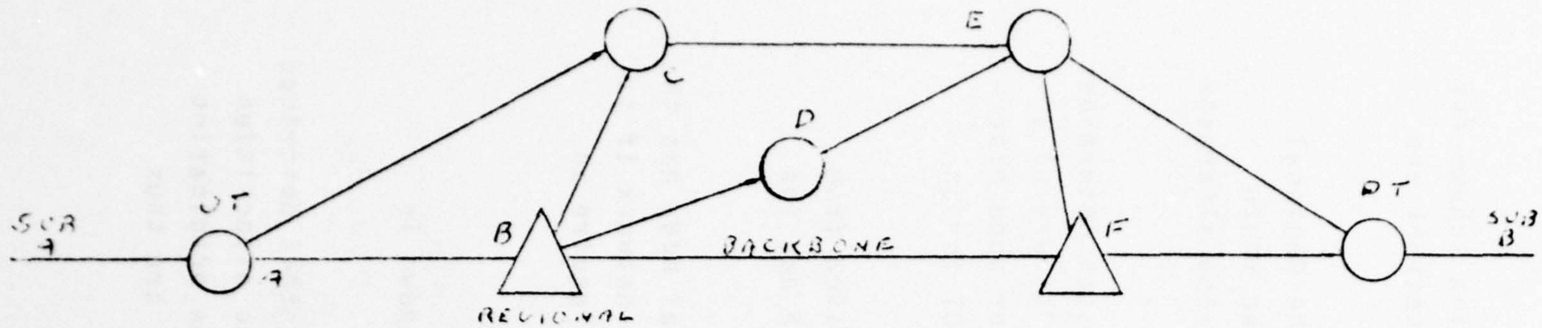
The OT passes network status information derived from acknowledgment messages to the regional which has the responsibility.

In determining the optimum route. the regional node has the option of routing a call over the "backbone" network if it is determined that the ultimate route would require an excess of two trunks.

3.2.2.2 Circuit Switched - Non-hierarchical

The routing rules for this combination are shown in Figure 3-8.

The basic difference between this method and that described above for the hierarchical network is in the disposition of the routing tables which now reside in the originating tributary. The primary and alternate routes are thus defined at the OT.



ROUTING RULES

1) FULL NETWORK CONNECTIVITY STORED AT REGIONALS - ONLY CURRENT ROUTES STORED IN OT.

2) ON SERVICE REQUEST FROM SUBSCRIBER A., OT SEEKS REGIONAL.

3) REGIONAL DETERMINES PRIMARY AND ALTERNATE ROUTE.

4) IF REGIONAL DETERMINES THAT DESTINATION DISTANCE EXCEEDS TWO LINKS, IT ROUTES CALL OVER BACKBONE NETWORK.

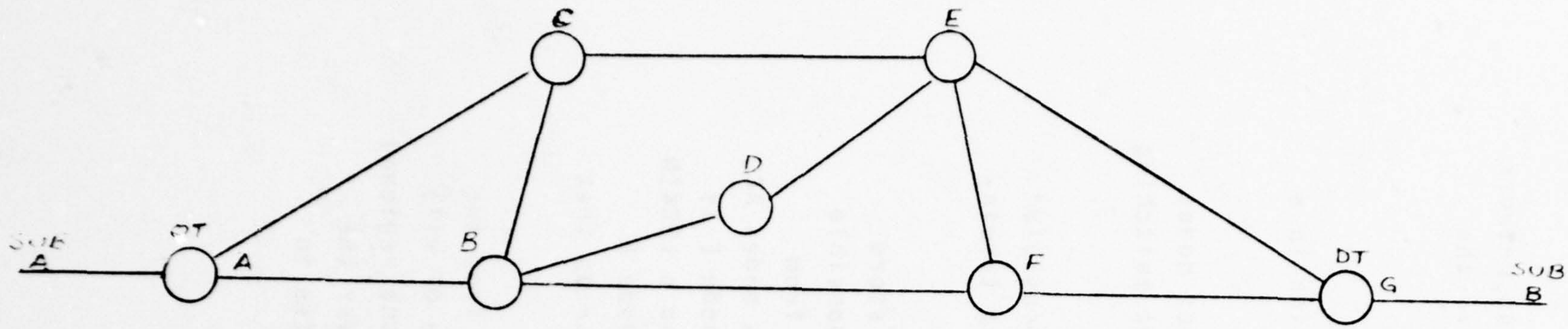
5) IF CALL IS NOT ROUTED OVER BACKBONE NETWORK - COMPLETE PRIMARY ROUTE WITH ALTERNATE RETURNED TO OT.

6) OT ATTEMPTS PRIMARY ROUTE AND IF THIS PATH CANNOT BE USED CALL REVERTS TO OT FOR ALTERNATE ROUTE HANDLING.

7) FROM (6), OT NOTES NODE AT WHICH PRIMARY PATH OBSTRUCTION IT FOUND. IF THIS OCCURS ON SUCCESSIVE CALLS, INFORMATION SENT TO REGIONAL AND LINK REMOVED FROM TABLES.

8) FAILURE OF ALTERNATE RECORDS OTHER FAILURES AND CALL IS ABANDONED. (DETERMINED AT OT)

FIGURE 3-7 - ROUTING RULES - DETERMINISTIC - CIRCUIT SWITCHED - HIERARCHICAL



<u>ROUTING RULES</u>

1) FULL NETWORK CONNECTIVITY STORED IN ALL NODES.
2) PRIMARY ROUTE AND ONE ALTERNATE SPECIFIED BY OT.
3) PRIMARY ROUTE ATTEMPTED AND LINKS RESERVED AT EACH SUCCESSIVE NODE.
4) IF CALL FAILS ON PRIMARY ROUTE, CALL REVERTS TO OT FOR ALTERNATE ROUTE HANDLING.
5) FROM (4) OT NOTES POINT OF FAILURE. IF THIS FAILURE OCCURS ON SUCCESSIVE CALLS DEFECTIVE LINK REMOVED FROM TABLE.
6) FAILURE OF ALTERNATE RECORDS OTHER LINK FAILURES AND ABANDONS CALL.

FIGURE 3-8 - ROUTING RULES - DETERMINISTIC - CIRCUIT SWITCHED - NON-HIERARCHICAL

Since the regional node is not required a backbone network no longer exists. However. the OT will still have the capability of defining the optimum path.

3.2.2.3 PNR - Hierarchical

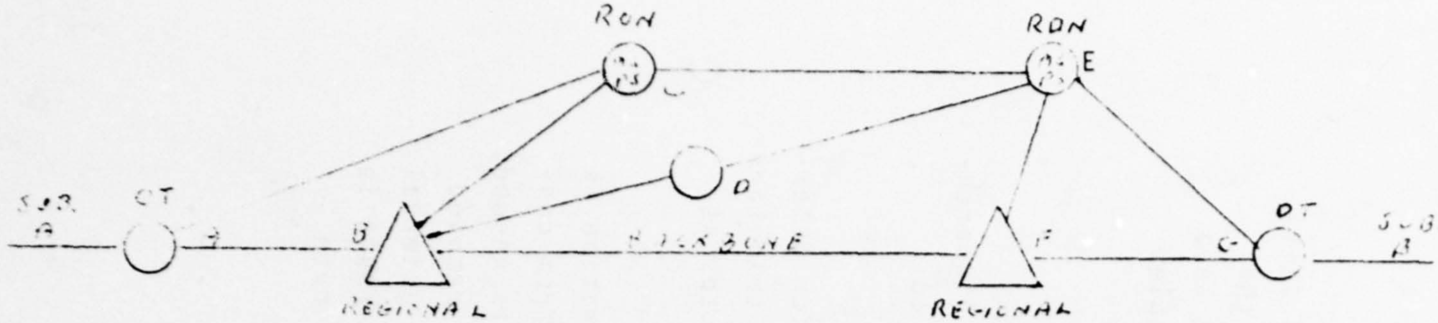
The routing rules for packet or message information in a hierarchical network are shown in Figure 3-9.

The hypothetical network in this figure shows that nodes C & E are designated as having packet and message switching capability in addition to circuit switching.

Furthermore. these nodes are designated as "responsible" nodes to subscribers A and B, the originating and terminating subscribers respectively.

A responsible node,because of its capability to store messages, is used to route a message as far as possible through the network. For example, if a message from subscriber A is to be routed to subscriber B via nodes AC, E & G and if the trunk between C & E is out or node E is blocked, Node C as the responsible node will send a LOCKIN to Node A. The message will be transmitted to Node E which will now become the originating node as far as that particular message is concerned.

As with a voice call, the OT derives its routes from the connected regional and the route returned to the OT will consist of the primary and an alternate. Also the regional has power of decision on the routing of calls over the backbone network if alternate routes would require in excess of two links.



ROUTING RULES:

1) FULL NETWORK CONNECTIVITY STORED IN ALL NODES.

2) ON SERVICE REQUEST FROM SUB. A, OT SEEKS NEAREST REGIONAL.

3) REGIONAL DETERMINES CLOSEST RON TO OT, CLOSEST RDN TO DESTINATION AND COMPLETES PATH.

4) IF REGIONAL DETERMINES THAT DESTINATION DISTANCE EXCEEDS TWO LINKS, IT SPECIFIES ROUTE OVER BACKBONE NETWORK. (DEST. DISTANCE = OT + DN)

5) IF CALL IS NOT ROUTED OVER BACKBONE NETWORK - COMPLETE PRIMARY ROUTE WITH ALTERNATE RETURNED TO O.T.

6) OT ATTEMPTS PRIMARY ROUTE AND IF FAILURE IS ENCOUNTERED CALL REVERTS TO OT FOR ALTERNATE ROUTE HANDLING.

7) FROM (6) OT NOTES POINT OF FAILURE. IF THIS FAILURE OCCURS ON SUCCESSIVE CALLS, INFORMATION SENT TO REGIONAL AND LINK REMOVED FROM TABLES.

8) FAILURE OF ALTERNATE RESULTS IN FULL MESSAGE BEING SENT TO RON IF IT CAN BE REACHED. RON THEN TAKES OVER ROUTE DETERMINATION.

9) IF RON CANNOT BE REACHED IN SUCCESSIVE ROUTING ATTEMPTS, CALL IS ABANDONED AND SUB. A NOTIFIED.

FIGURE 3-9 - ROUTING RULES - DETERMINISTIC - MESSAGE OR PACKET SWITCHED - HIERARCHICAL

3.2.2.4 PNR - Non-hierarchical

The deterministic routing of PNR traffic in a non-hierarchical network uses the rules as shown in Figure 3-10. This differs from the hierarchical network by the exclusion of designated regional nodes and the backbone network. In comparison to circuit switched non-hierarchical it differs in the provision of responsible nodes.

Route determination is made at the OT and failed calls revert to the OT for alternate routes. As with the hierarchical network, a PNR message is forwarded to a responsible node if the full route is not available.

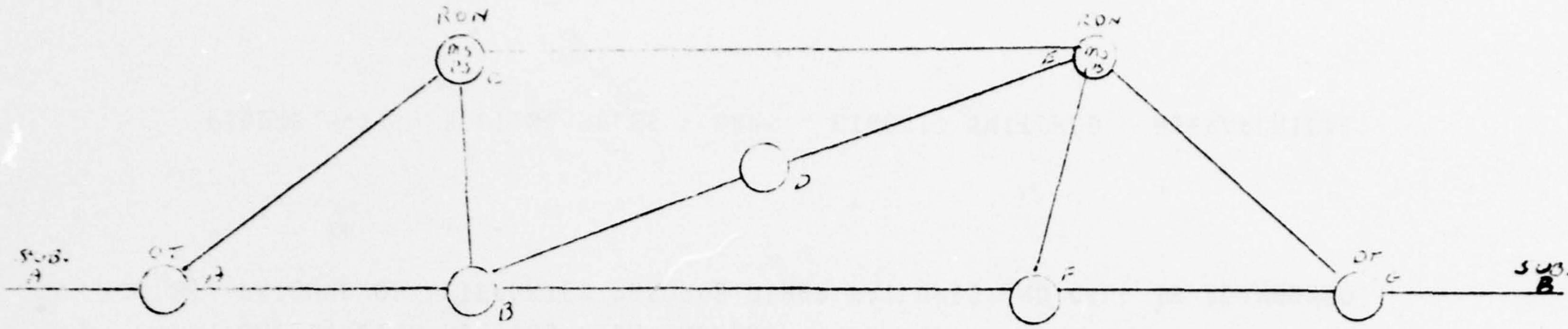
3.2.3 DART

3.2.3.1 Circuit Switch - Hierarchical

Routing rules for circuit switched traffic in a hierarchical network using the DART technique are shown in Figure 3-11.

Routing tables are contained in the regional which determines the route on request from the originating tributary to which it passes the primary and alternate routes as requested.

If a route fails due to a busy link, this information is passed to the regional which removes this link from consideration only for the next trial in which it is needed. If a call fails due to link outage, the link is removed from further consideration until re-instated by external means (network control). With DART, a tertiary route is determined if required by use of the calculated path technique.



ROUTING RULES:

1) FULL NETWORK CONNECTIVITY STORED IN ALL NODES.

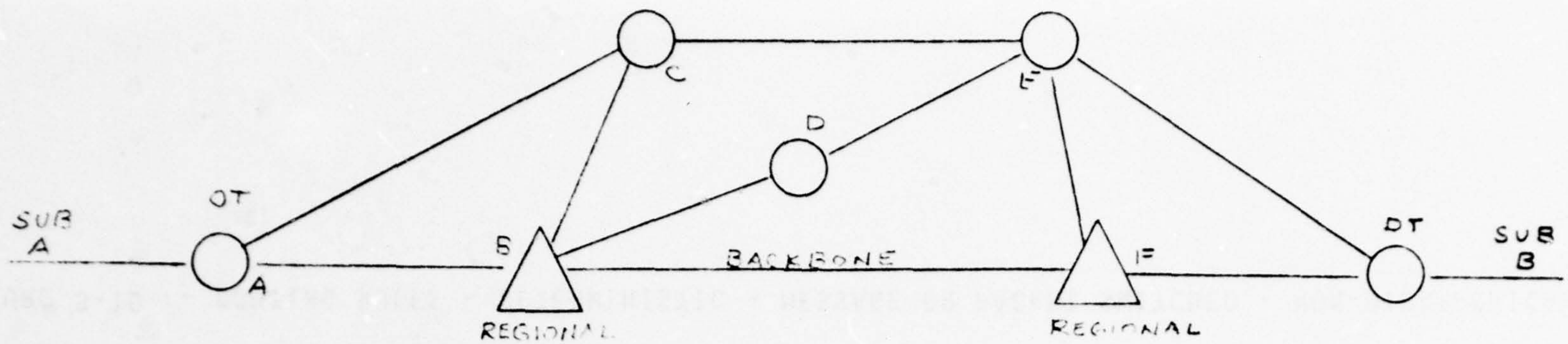
2) ON SERVICE REQUEST FROM SUB A, OT DETERMINES RON, RDN AND PRIMARY AND ALTERNATE ROUTE BETWEEN SUBSCRIBERS.

3) IF PRIMARY ROUTE FAILS, CALL RETURNS TO OT WITH INFORMATION ON POINT OF FAILURE. FAULTY LINK IS REMOVED FROM PATHS.

4) IF SECONDARY ROUTE FAILS BUT RON HAS BEEN REACHED, COMPLETE MESSAGE IS SENT TO RON WHICH TAKES OVER ROUTE DETERMINATION.

5) IF RON CANNOT BE REACHED ON SUCCESSIVE ROUTING ATTEMPTS CALL IS ABANDONED AND SUB IS NOTIFIED.

FIGURE 3-10 - ROUTING RULES - DETERMINISTIC - MESSAGE OR PACKET SWITCHED - NON-HIERARCHICAL.



ROUTING RULES:

1) FULL NETWORK CONNECTIVITY STORED AT REGIONALS.
2) ON SERVICE REQUEST FROM SUB A, OT SEEKS REGIONAL.
3) REGIONAL DETERMINES PRIMARY.
4) IF REGIONAL DETERMINES THAT DESTINATION DISTANCE (OT TO DT) EXCEEDS TWO LINKS IT ROUTES CALL OVER BACKBONE NETWORK.
5) WHETHER OR NOT, THE CALL IS ROUTED OVER BACKBONE NETWORK - COMPLETE PRIMARY ROUTE RETURNED TO OT.
6) OT ATTEMPTS PRIMARY ROUTE AND IF FAILURE IS ENCOUNTERED CALL REVERTS TO OT. OT REQUESTS ALTERNATE FROM REGIONAL (INDICATING LINKS) TO BE REMOVED.
7) FROM (6) REGIONAL NOTES POINT OF FAILURE. IF THIS FAILURE OCCURS ON SUCCESSIVE CALLS, LINK REMOVED FROM TABLES.
8) FAILURE OF ALTERNATES RECORDS OTHER FAILURES AND CALL IS ABANDONED.

FIGURE 3-11 - ROUTING RULES - DART - CIRCUIT SWITCHED - HIERARCHICAL.

3.2.3.2 Circuit Switched - Non-hierarchical

Routing rules for circuit switched non-hierarchical using the DART technique are shown in Figure 3-12. These rules are similar to those for the hierarchical network except that responsibility for determining primary and alternate routes and for calculating the tertiary route is vested in the OT which maintains and updates routing tables otherwise performed by the regional node.

3.2.3.3 PNR - Hierarchical

The routing rules for this technique are as shown in Figure 3-13.

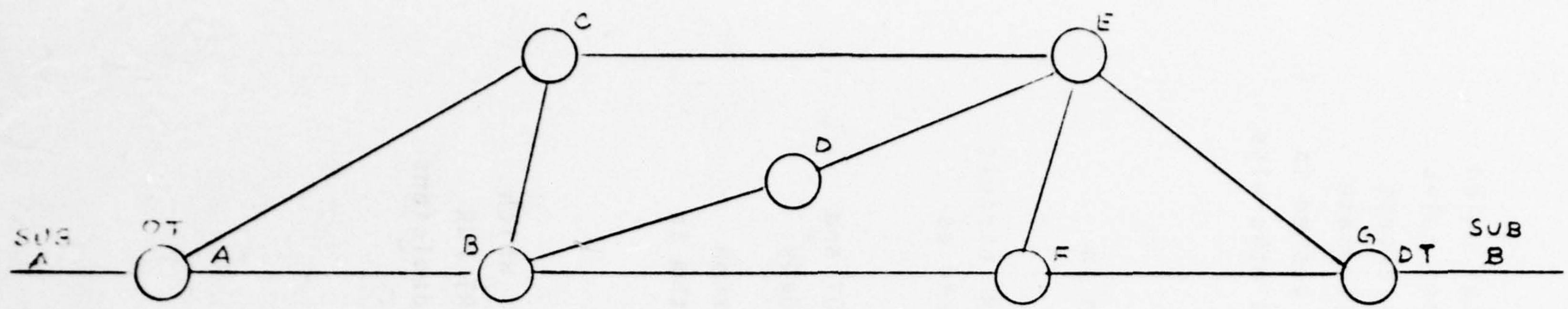
As with deterministic routing certain nodes have circuit and message switching capability and are designated as responsible nodes.

Routes are determined from the regionals by the OT and failures are passed to the regional for table update.

Any given call tries a primary and alternate and then tertiary which is determined by the PCALC algorithm in the regional.

3.2.3.4 PNR - Non-hierarchical

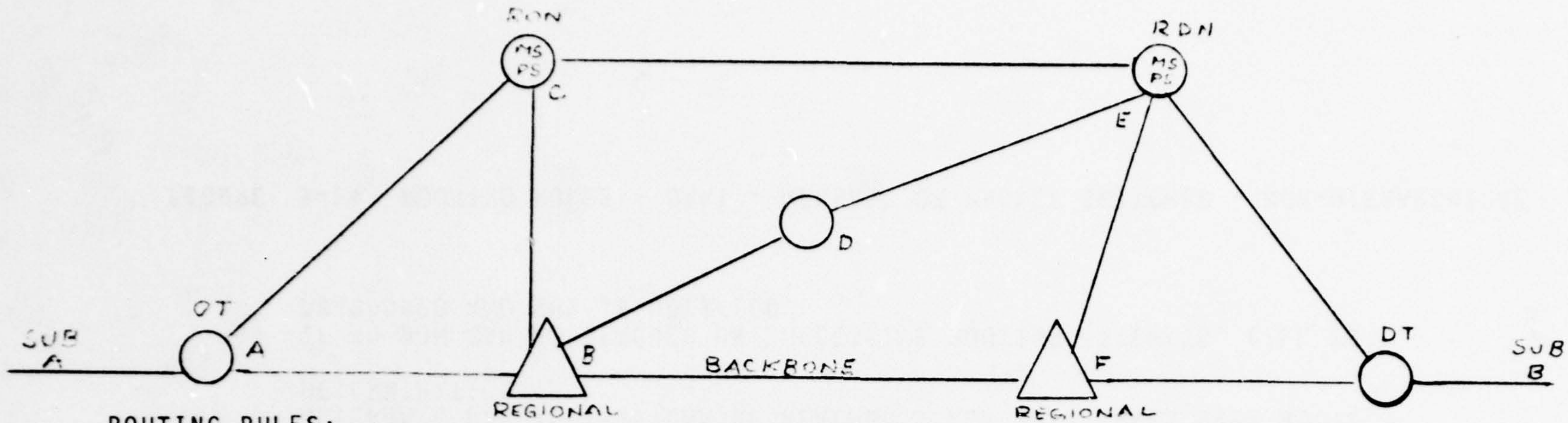
The PNR non-hierarchical routing scheme, rules of which are shown in Figure 3-14, is identical to the DART PNR non-hierarchical scheme except that the routing decisions are made in the tributary node.



ROUTING RULES:

1) FULL NETWORK CONNECTIVITY STORED IN ALL NODES.
2) PRIMARY ROUTE AND TWO ALTERNATES SPECIFIED BY OT.
3) PRIMARY ROUTE ATTEMPTED AND LINKS RESERVED AT EACH SUCCESSIVE NODE.
4) IF CALL FAILS ON PRIMARY ROUTE, CALL REVERTS TO OT FOR ALTERNATE ROUTE HANDLING.
5) FROM (4) OT NOTES POINT OF FAILURE. IF THIS FAILURE OCCURS ON SUCCESSIVE CALLS DEFECTIVE LINK REMOVED FROM TABLE.
6) FAILURE OF ALTERNATES RECORDS OTHER LINK FAILURES AND ABANDONS CALL.

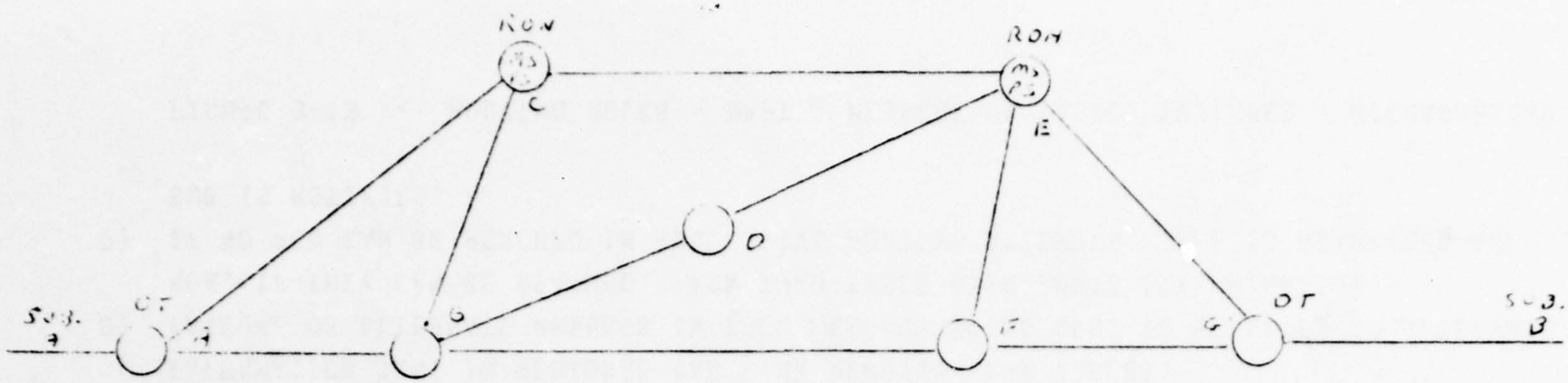
FIGURE 3-12 - ROUTING RULES - DART - CIRCUIT SWITCHED - NON-HIERARCHICAL.



ROUTING RULES:

1) FULL NETWORK CONNECTIVITY STORED IN ALL NODES.
2) ON SERVICE REQUEST FROM SUB A, OT SEEKS NEAREST REGIONAL.
3) REGIONAL DETERMINES RON'S AVAILABLE TO OT AND RDN'S AVAILABLE TO DT AND SELECTS COMPLETE PATH, PRIMARY.
4) IF REGIONAL DETERMINES THAT DESTINATION DISTANCE EXCEEDS TWO LINES, CALL MUST BE ROUTED OVER BACKBONE.
5) WHETHER OR NOT CALL IS ROUTED OVER BACKBONE, COMPLETE PATH RETURNED TO OT.
6) OT ATTEMPTS PRIMARY ROUTE AND IF FAILURE IS ENCOUNTERED, CALL REVERTS TO OT FOR ALTERNATE ROUTE HANDLING.
7) FROM (6) OT NOTES POINT OF FAILURE. IF THIS FAILURE OCCURS ON SUCCESSIVE CALLS INFORMATION SENT TO REGIONAL AND LINK REMOVED FROM TABLES.
8) FAILURE OF ALTERNATE RESULTS IN FULL MESSAGE BEING SENT TO SELECTED OR ALTERNATE RON, IF THEY CAN BE REACHED. RON THEN TAKES OVER ROUTE DETERMINATION.
9) IF NO RON CAN BE REACHED IN SUCCESSIVE ROUTING ATTEMPTS, CALL IS ABANDONED AND SUB IS NOTIFIED.

FIGURE 3-13 - ROUTING RULES - DART - MESSAGE OR PACKET SWITCHED - HIERARCHICAL



ROUTING RULES:

1) FULL NETWORK CONNECTIVITY STORED IN ALL NODES.

2) ON SERVICE REQUEST FROM SUB A, OT DETERMINES RON'S AVAILABLE TO OT AND RDN'S TO DT AND SELECTS COMPLETE PATH (PRIMARY AND TWO ALTERNATES).

3) OT ATTEMPTS PRIMARY ROUTE and IF FAILURE IS ENCOUNTERED, CALL REVERTS TO OT FOR ALTERNATE ROUTE HANDLING.

4) FROM (3) OT NOTES POINT OR FAILURE. IF THIS FAILURE OCCURS ON SUCCESSIVE ROUTING ATTEMPTS, LINK IS REMOVED FROM TABLES.

5) FAILURE OF ALTERNATE RESULTS IN FULL MESSAGE BEING SENT TO SELECTED OR ALTERNATE RON IF THEY CAN BE REACHED. RON THEN TAKES OVER ROUTE DETERMINATION.

6) IF NO RON CAN BE REACHED ON SUCCESSIVE ROUTING ATTEMPTS, CALL IS ABANDONED AND SUB IS NOTIFIED.

FIGURE 3-14 ROUTING RULES - DART - MESSAGE OR PACKET SWITCHED - NON-HIERARCHICAL

3.2.4 CALCULATED PATH-ROUTING ALGORITHM

The following describes the routing algorithm used for calculating a path through the network. The algorithm is resident at Regional nodes only in the hierarchical network and in all nodes in the non-hierarchical network.

The principles of the algorithm are described in this section and detailed flow charts of the program are given in Appendix E (Program Documentation).

3.2.4.1 Basic Assumptions

In order to define the calculated path algorithm, certain basic ground rules were established below:

1. A path is obtained using the routing algorithm from the originating node (ON) to the destination tributary (DT).
   - o Traffic originating and terminating in the same node is not handled in the routing algorithm.
   - o Traffic to adjacent nodes one link away is handled by the algorithm.
2. If a path is available, meeting certain minimum requirements (described later), this path is found.
3. If no path is available, the message is returned with this information in P75 (Path Connection).
4. Path-Request Paths are generated:
   - o ON-Responsible Regional (RR) for normal traffic.
   - o ON-RR-Gateway (GW) for traffic to mobile subscriber.

5. "Disconnected Nets", networks severed into two or more distinct subnetworks, are permitted.

6. Path type is determined by message type: CS, MS, PS. (Circuit Switch, Message Switch, Packet Switch)

7. One or some combination of the following path types are generated:

   - o Direct (least links).
   - o Supernet (high-density trunks).
   - o RPM (Responsible Packet-Message Switch Nodes) for MS or PS traffic.

8. Any node which is a PM (Packet-Message Switch) node is assigned as its own RPM.

9. Traffic may not terminate in a Regional node.

3.2.4.2 Calculated Path Decision Table

Table 3-1 presents a dicision table for message handling in the calculated path algorithm. This table is read in a vertical direction and the number(s) at the foot of each column indicates the next column to be read. Double numbers at the foot of each column indicate message to be sent to both columns.

The key to the lettering of the columns is as follows:

Column	Mnemonic	Meaning
1	MT	Message Type
2	RG	Regionals
3	CSP	Circuit Switched Path
4	RPMP	RPM Path
5	MBS	Mobile Subscriber

COLUMN	1-MT		2-RG		3 - CSP					4 RPMP														5MBS		6PRP					7RET			8 DP	
CONDITION	A	B	A	B	A	B	C	D	E	A	B	C	D	E	F	G	H	I	J	K	L	M	N	A	B	A	B	C	D	E	A	B	C	A	B
1. CS?	Y	N																																	
2. MS-PS?	N	Y																																	
3. MBL SUB?																								Y	N	N	Y	-	Y	Y					
4. D.N.≤2?			Y	N																															
5. DIRECT PATH?					-	Y	N	N	N	-	Y	Y	Y	N	N	N	N	N	Y	N	N	N	-												
6. P27 - DT?										Y	-	N	N	-	N	N	N	N	Y	N	N	N	N												
7. P27 = DRPM?										N	Y	-	-	Y	-	N	N	N	Y	Y	N	N	N												
8. P27 = OPPM?										N	N	Y	Y	N	N	N	Y	Y	Y	N	Y	Y	N												
9. P27 = DR?					N	N	N	Y	-	N	N	N	N	N	Y	-	N	N	N	Y	Y	Y	N												
10. P27 = CP?					N	N	N	N	Y	N	N	N	N	N	N	Y	-	-	N	Y	Y	Y	N												
11. P27 = CN?					Y	N	N	N	N	N	N	N	Y	N	N	N	N	Y	N	N	Y	N	Y			-	N	Y	-	Y					
12. P27 = RR?																										Y	-	N	Y	Y					
13. P27 = GW?																										N	Y	N	N	Y					
14. OR, DR, CONN. OK?																																		Y	N
15. CONN. AVAIL?																															Y	Y	N		
16. PATH COMPLETE?																															N	Y	-		
ACTIONS																																			
1. TRY FIND OR				X																															
2. TRY FIND DR				X																															
3. OBTAIN DRPM		X																						X	X										
4. OBTAIN ORPM		X																						X											
5. OBTAIN RR										X																									
6. OBTAIN GW														X																					
7. P26 = DPPM															X																				
8. P26 = DR							X				X					X				X															
9. P26 = CP								X				X					X		X			X													
10. P26 = OPPM																												X							
11. P26 = ON						X			X																				X						
12. P26 = RR										X	X	X		X	X	X	X		X	X		X						X	X						
13. P26 = GW																																			X
14. OBTAIN RD	X	X		X		X	X	X	X																						X				
15. SET DIR. PATH			X																												X				
16. GET PATH																															X				
17. SET START																																X			
18. P57 = P56																										X	X			X					
19. TAG PATH OK																															X	X			
20. PATH COMPLETE																																			
21. RETURN																																			
GO TO COLUMN	2/3	2/4		8	5	7/3	7/3	7/3	7/3	7/4	7/4	7/4	5	7/4	7/4	7/4	7/4	5	7/4	7/4	5	7/4	5	6	6	7	7	7/6	7/6	7					

TABLE 3-1 - PATH CALCULATOR DECISION TABLE

Key to lettering of columns (continued):

Column	Mnemonic	Meaning
6	PRP	Path Request Path
7	RET	Return
8	DP	Direct Path

Figure 3-16 presents the flow through the table of all possible path combinations. The lettering above each of these paths indicates the columns in Table 3-1.

The specific path to be computed for a given message is constrained by message type, nodal distance and node types.

The specific constraints are as follows:

A. CIRCUIT SWITCHED (CS) TRAFFIC:

1. ON must be originating tributary (OT).
2. If minimum nodal distance (OT-DT) $\leq$ 2 links, direct path is generated from OT to DT.
3. If minimum nodal distance (OT-DT) $>$ 2 links, then an attempt is made to find a supernet path (high density trunks between Regional nodes):
    - Randomly select a Regional node as close as possible to the OT (Originating Regional: OR).
    - Randomly select a Regional node as close as possible to the DT (Destination Regional: DR).
    - Find direct path (OT-DT) if OR or DR not available (to meet Assumption 2).
    - Direct Path: DT-DR.
    - Supernet: DR-OR.

- o Find direct path (OT-DT) if no path between DR and OR is available (to meet Assumption 2).
- o Direct Path: OR-DT.

B. MESSAGE OR PACKET SWITCHED (MS-PS) TRAFFIC:

1. ON may be OT or a Liable Packet-Message Switched node (tributary or Regional).
2. The Originating Responsible PM node (ORPM) is found for the ON and the Destination Responsible PM node (DRPM) is found for the DT.
3. No path is found if the ORPM or the DRPM cannot be found, or if they cannot be incorporated in the path (because of lack of connectivity).
4. Direct Path: DT-DRPM.
5. *If minimum nodal distance (ORPM-DRPM)* $\leq$ *2 links,* direct path is generated from DRPM to ORPM.
6. If minimum nodal distance (ORPM-DRPM) $>$ 2 links, an attempt is made to find a Supernet path:
   - o OR and DR picked as in CS traffic except with reference to ORPM and DRPM, respectively.
   - o If the ORPM is also a Regional node, it is always made the OR.
   - o If the DRPM is also a Regional node, it is always made the DR.
   - o Find direct path from DRPM to ORPM if OR and/or DR not available (to meet Assumption 2).
   - o Direct Path: DR to OR.

- o Supernet Path: DR to OR.
- o Find direct path from DRPM to ORPM if path from DR to OR unavailable (to meet Assumption 2).
- o Direct Path: OR to ORPM.
- o Direct Path: ORPM to ON.

3.2.4.3 Testing the Path Calculator

The Path Calculator is a subroutine incorporated into the Traffic Generator, and requires four subroutines already available in the Traffic Generator: OBTNN, RNDRG, GNODE, GPATH. The Path Calculator, however, is not tested within the normal Test sequence of the Traffic Generator. Instead, a separate test deck is developed and maintained (concurrently with Traffic Generator revisions). This deck provides an iterative calling routine to generate a set of messages which forces the Path Calculator to calculate paths exercising all the columns in the Decision Table. The path formats necessary to do this are shown in Figure 3-16 a) through c). The paths to be followed for testing are:

Figure (a): 1,3
Figure (b): 1,4,6
Figure (c): 1,17,21,23
Figure (c): 26,27,29

Network input and CIDI matrices are also provided in this deck. Network A (used in Acceptance Tests) can be the basis for obtaining path formats 1-3, but a modified version of this net is necessary to provide the connectivity

required to produce format 4.

3.2.4.4 Modifying Connectivity

PCALC finds a path based on the current connectivity provided by the CIDI matrices; therefore, a routine to modify CIDI and call PCALC is needed. The Network Simulator will call this routine, providing the link(s) which are to be removed from the connectivity. This routine is called 'TDR' and a functional block diagram is shown in Figure 3-15.

3.3 STATE DIAGRAM DESCRIPTION

3.3.1 INTRODUCTION

The following presents a description of the protocol used in the simulation to define the passage of transactions through the simulation model. The state diagrams are shown in Figure 3-17 which includes protocols for the delivery of voice messages and packet messages with store and forward operation. Detailed decision tables are given in Appendix II.

3.3.2 CIRCUIT SWITCH (CS)

3.3.2.1 Routing Between Origin and Destination

Circuit switch protocol is shown in Figure 3-17 in which the originating node is shown on the left and the destination on the right. It should be noted that intermediate nodes may be located between the point of origin and the destination and that a connection request can encounter a blocked node or a busy trunk condition at any of these intermediate points. This situation will become apparent from the description.

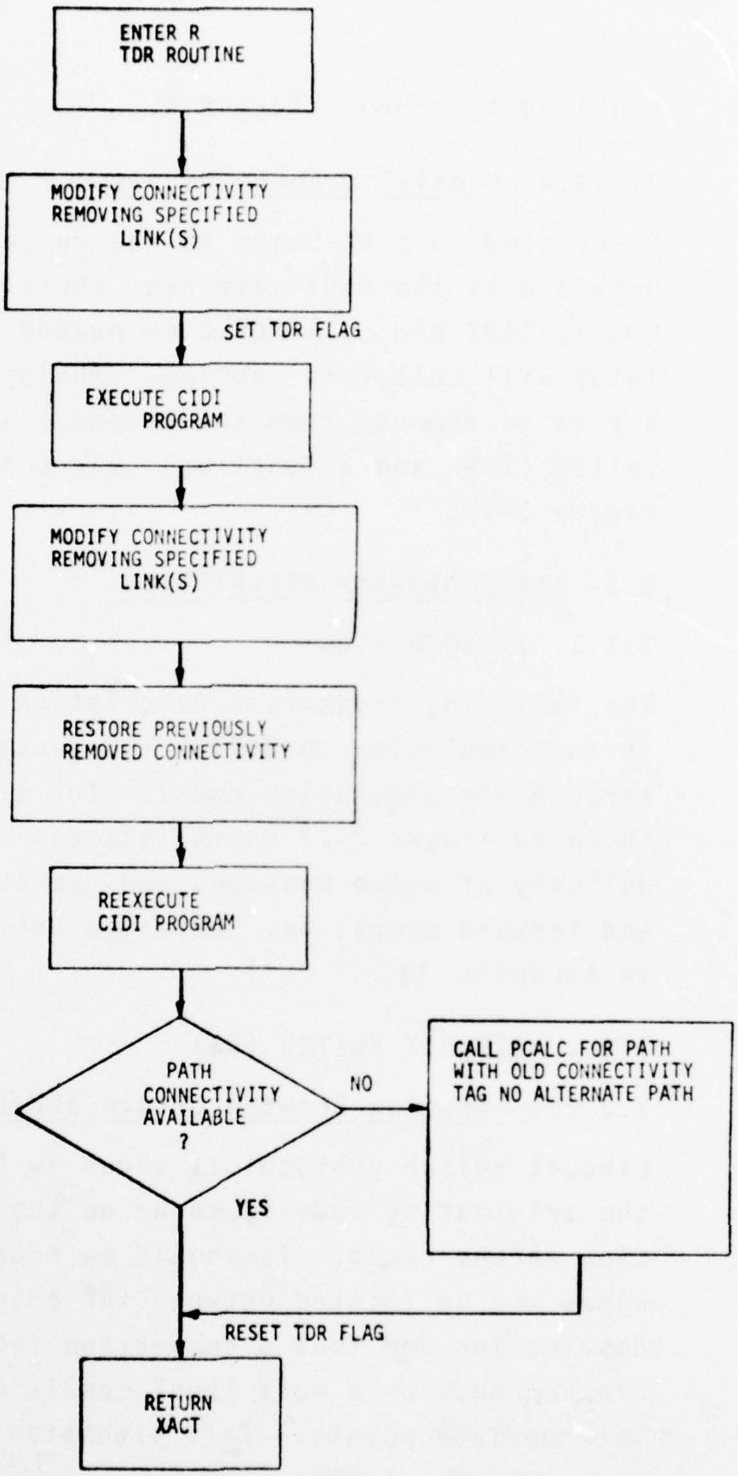


FIGURE 3-15 TRAFFIC DESTINATION ROUTINE (TDR)

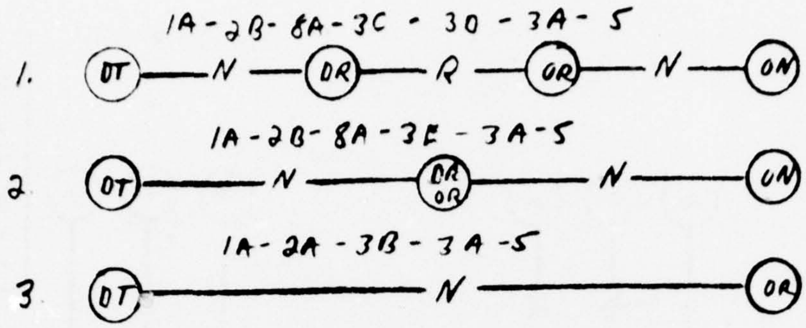


FIGURE 3-16 (a) - POSSIBLE CS PATHS

*NOTE = NUMBERS ABOVE PATHS REFER TO PATH BY COLUMNS THROUGH THE DECISION TABLE 3-1.

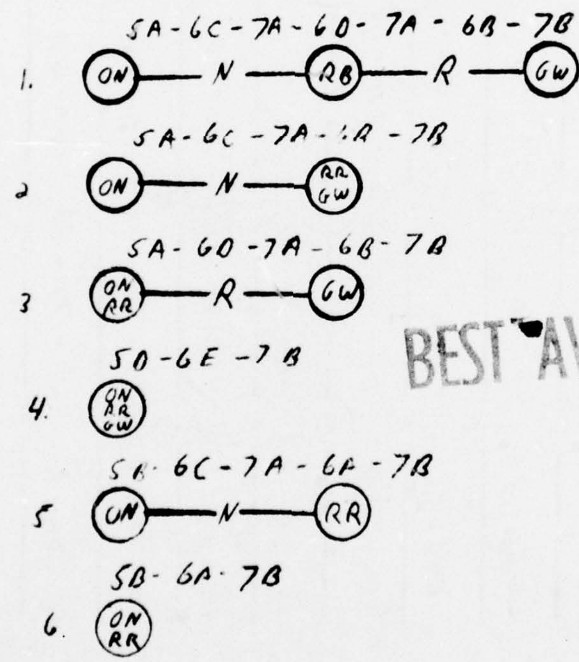
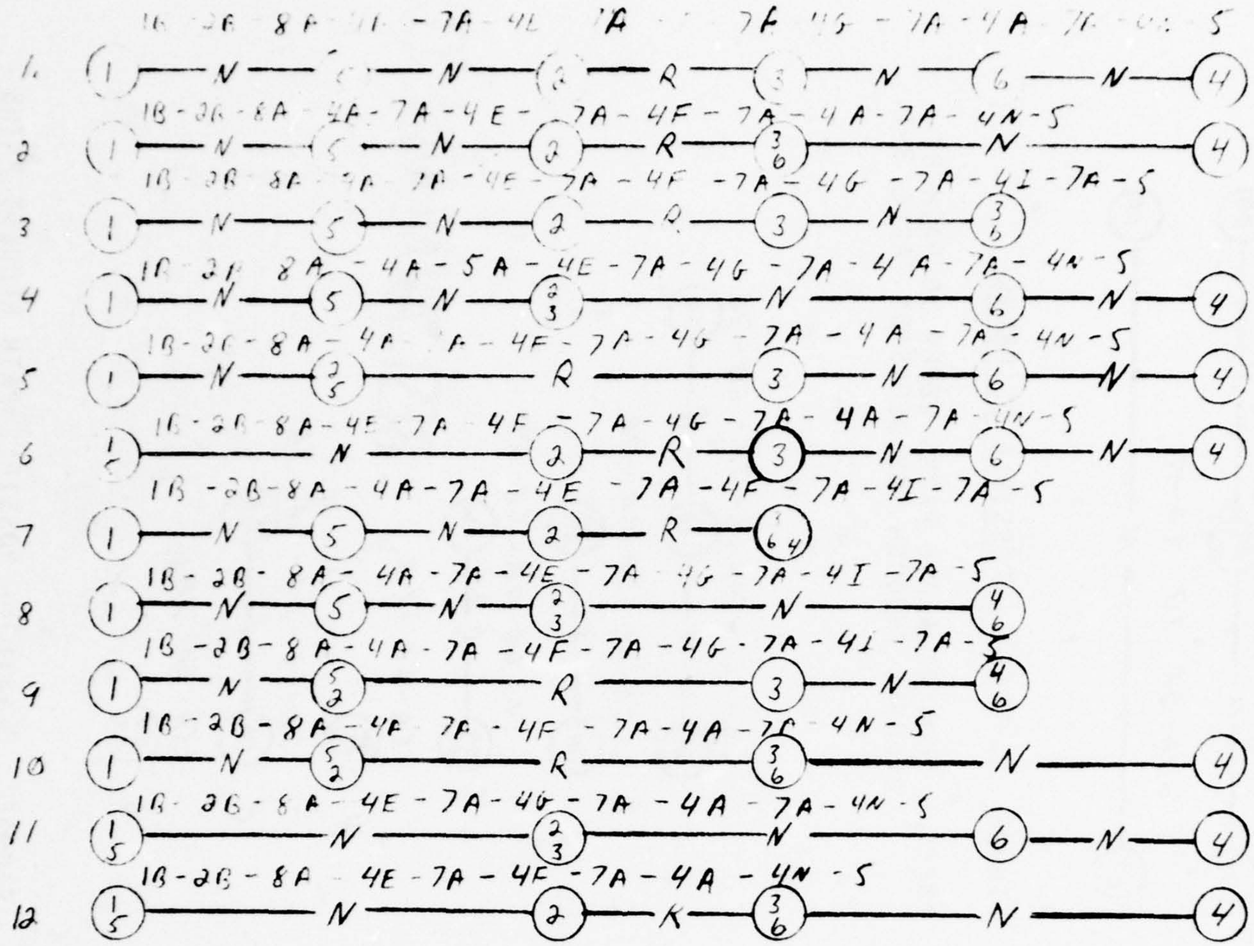


FIGURE 3-16 (b) - POSSIBLE PATH REQUEST PATHS



1 = DT	4 = ON
2 = DR	5 = DRPM
3 = OR	6 = ORPM

FIGURE 3-16 (c) POSSIBLE RPM PATHS

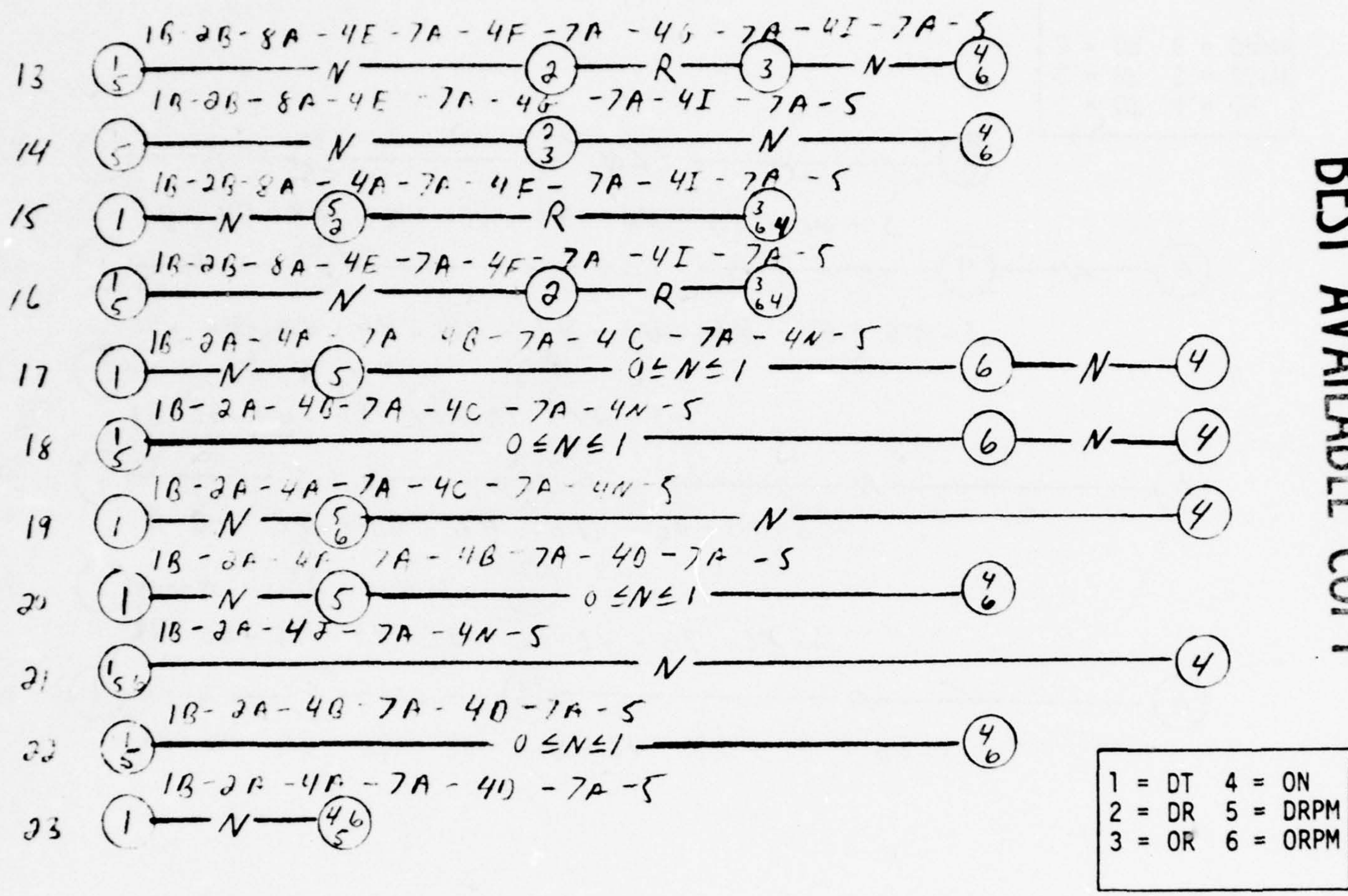


FIGURE 3-16 (c) (CONT'D) POSSIBLE RPM PATHS

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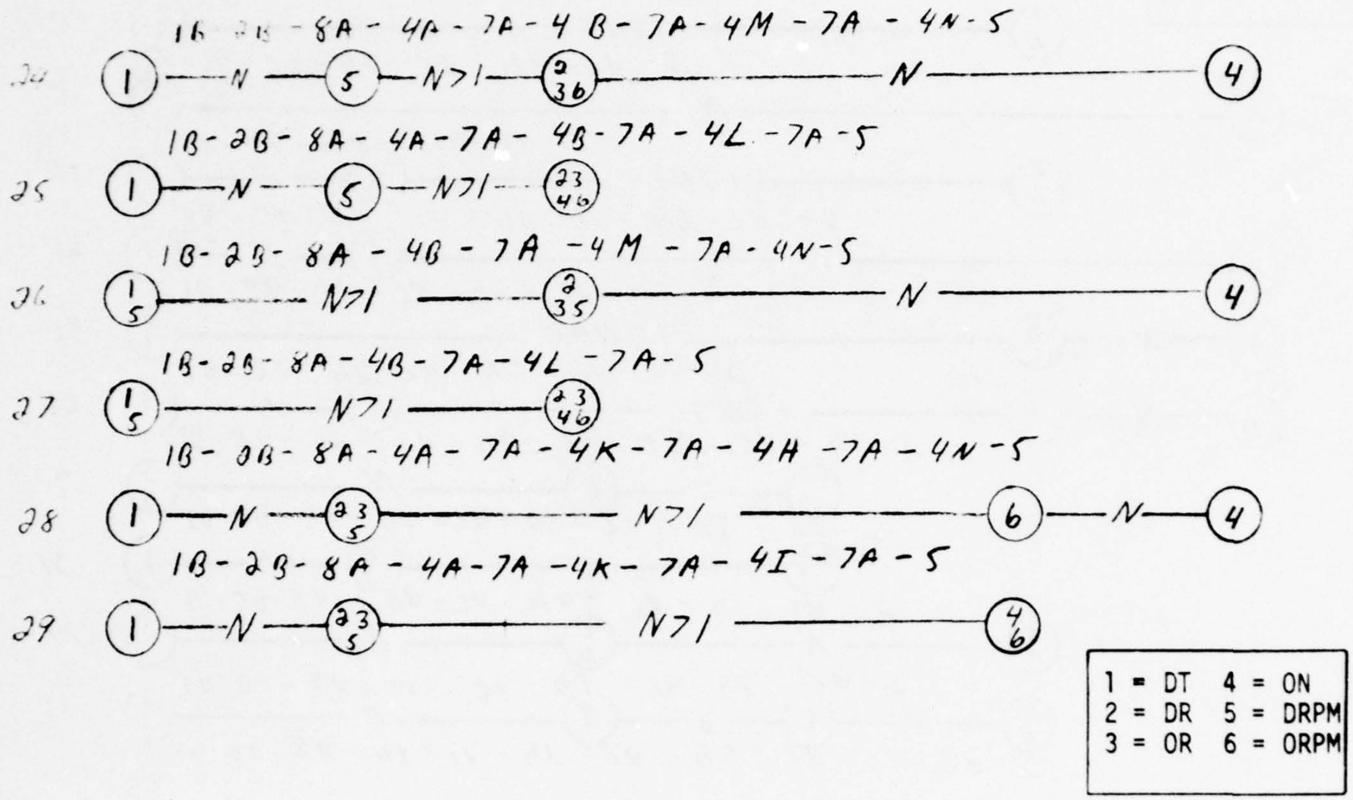

FIGURE 3-16 (c) (CONT'D) POSSIBLE RPM PATHS

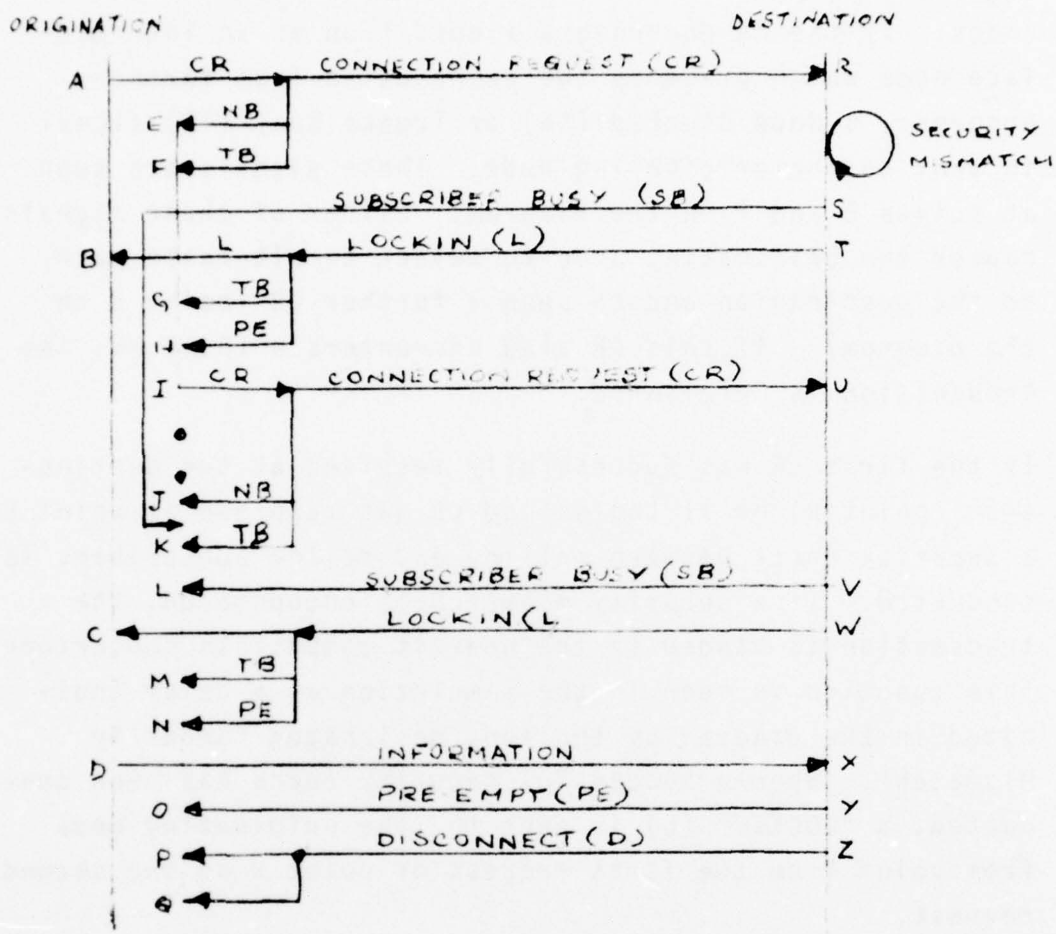

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FIGURE 3-17 - CIRCUIT SWITCHED PROTOCOL

A call is originated at point A through a connection request (CR) to the destination node via any intermediate nodes. If the CR encounters a condition at an intermediate node which prevents the transaction from further progress, a Node Blocked (NB) or Trunks Busy (TB) signal is sent to the originating node. These signals are seen at points E and F on the diagram. Either of these signals causes the originating node to select an alternate path to the destination and to send a further CR (point I on the diagram). If this CR also encounters a TB or NB, the transaction is terminated.

If the first CR was successfully received at the destination (point R) or if the second CR was received at point U, a security check between calling and called subscribers is conducted. If a security mismatch is encountered, the transaction is handed to the nearest compatible subscriber. This function is seen in the simulation as a delay indicated in the diagram by the loop designated "Security Mismatch". When a successful security check has been conducted, a "LOCKIN" (L) is sent to the originating node from point T on the first request or point W on the second request.

It should be noted that the simulation is arranged such that although a "path" is reserved during the CR, the facilities are not taken into service until LOCKIN. This can result in the received facility being busied or preempted before the "call" can be completed. These conditions result in a Trunks Busy (TB) or Pre-empt (PE) appearing at points G & F on the first CR and will result in a new CR from point I. If the busy or pre-empt condition is encountered on the second CR, the TB or PE signals will appear at points M & N respectively and the call will

be terminated.

A successful LOCKIN received at points B or C will result in a completed call and information will flow as shown from point D to X.

If, during the connect time a call is pre-empted, the PE signal (Point O) will cause a termination of the call.

Normal release will result in a "DISCONNECT" (D) signal appearing at Point P. If the disconnect signal encounters a pre-empt before being operative, a Pre-empt (PE) signal appears at point Q and the call is terminated. This latter (pre-empt) condition would not occur in practice but was included in the simulation as a point for gathering statistics.

3.3.3 PACKET/NARRATIVE RECORD (PNR) PROTOCOL

3.3.3.1 Routing from Origination to RDN

Figure 3-18 shows the signal flow for packet and message switching from an originating tributary node via a responsible originating node (RON), a responsible destination node (RDN) to a destination node. As with the circuit switch protocol, it is possible that intermediate nodes will be encountered between the RON and the RDN. An elaboration of the signal flow between these intermediate points is shown between the RON and a liable node (LN) in Figure 3-19 and between the liable node and the RDN in Figure 3-20.

Referring first to Figure 3-17 a connection request (CR) from the originating tributory node (Point AA) will seek a path to the RON. In order to arrive at the RON, intermediate nodes could be encountered. If either an

intermediate node encounters a blocked node condition or if an intermediate node encounters a blocked trunk condition, a NB or TB signal (points BA & BB respectively) will result in a second connection request (point BE) being transmitted over an alternate path. If this second CR encounters an TB or NB condition (points BF & BG) the call is terminated (point BN). If either of the CR's is successful in finding a path, a LOCKIN signal from the RON (Point CC) is received by the originating node at Point AB or AC.

Paths through intermediate nodes are reserved during the CR period but are not actually taken into service until LOCKIN is returned. If a reserved trunk is taken into service or pre-empted by another call before LOCKIN occurs, a Trunk Busy (TB) or pre-empt (PE) signal is received at the point of origination (Points BC and BD). If this occurs after the first CR a second attempt is made (Point BE). If it occurs on the second attempt (Points BI & BT) the calls are terminated.

A successful LOCKIN (Points AB or AC) results in the complete message being sent to the Responsible Originating Node (Point AD). If the facilities are pre-empted during transmission, a Pre-empt (PE) signal is received (Point BK) and transmission is discontinued.

On completion of transmission, a disconnect (D) signal is received by the originating node (Point BL).

If the disconnect signal encounters a pre-empt before being operative, a Pre-empt (PE) signal appears at the originating node (Point BM) and the call is terminated. This condition would not occur in practice but was included in the simulation as a statistical gathering point.

The complete message is now resident in the RON which is responsible for finding a path through the network to the destination node, packetizing the message if required, and re-transmitting the information.

3.3.3.2 Transfer Between RON and RDN

In Figure 3-18 the signal flow is shown when the responsible originating node is directly connected to the responsible destination node (RDN).

Finding a path to the RDN is the same as the method described between the originating node, except that after two unsuccessful CP's the information is placed in a delayed queue for a later attempt. Up to 20 attempts at obtaining a path are made for any given message and if after 20 attempts the call is still unsuccessful the message is considered as "lost."

The information is transferred in the following manner. If the information is in packet form each successful package receives a packet acknowledge (PACK) (Point FK) which results in the transfer of the next packet. If the information is the last packet in the message or a complete message in itself, the successful transmission results in a message acknowledge (MACK) (Point FL) which also causes release of the trunks. The "RON/RDN Signaling Terminated" designation is not normally used in practice but is included as a data gathering point in the simulation.

If a message is pre-empted at any point in the transmission shown by the pre-empt (PE) signal in the diagram (Points EJ, EK, EL, EM) the message is stored for later attempts in the delay queue and up to 20 attempts at

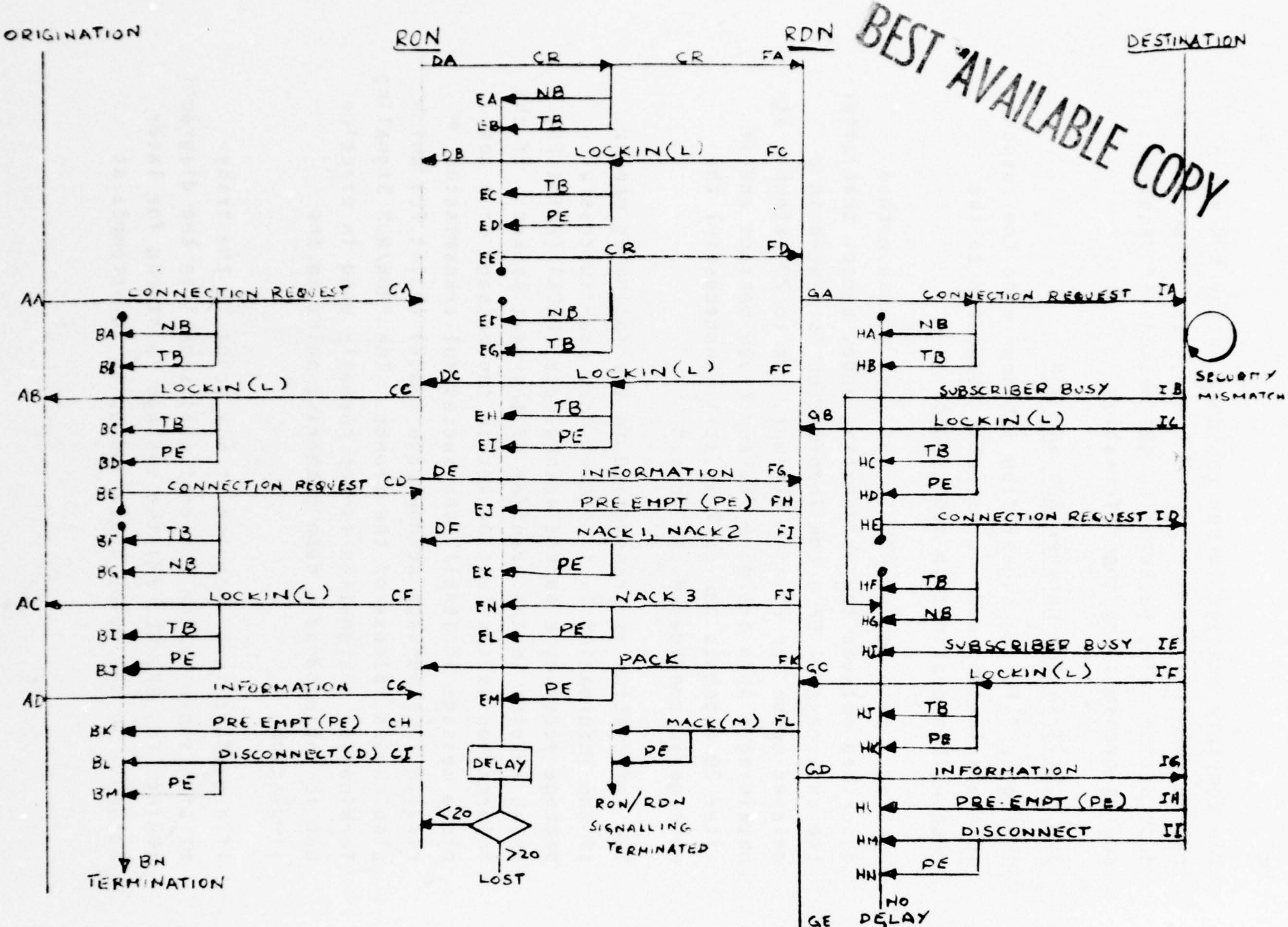


FIGURE 3-18 - PACKET & MESSAGE SWITCH PROTOCOL

retransmission are made, after which the message is considered "lost".

Messages which fail parity and other checks at the RDN receive negative acknowledge (NACK) signals. Three attempts at retransmission are made by the RON, the first two unsuccessful attempts being responded to by NACK 1 and NACK 2 (Point DF). If the third attempt fails NACK 3 (Point EN) is received which releases the path and places the entire message in the 20 attempt queue for later attempts.

When the entire message is resident in the RDN, the RDN attempts to deliver the entire message to the destination used.

3.3.3.3 Delivery from RON to RDN Via Intermediate Nodes

Certain nodes between the RON and the RDN are designated "Liable Nodes." Although these nodes have the same storage capability as the RON and RDN, this capability is not used unless the "Liable Node" fails to find a path forward. This situation is illustrated in Figure 3-19.

A CR from the RON is repeated by the liable node to the next node in an attempt to find a path. If this attempt is unsuccessful, a TB or NB signal is received by the liable node. The liable node on seeing this signal generates a LOCKIN to the RON and the information is transferred from RON to liable node in identical manner as described above for transfer between RON and RDN.

The path determination and message transfer between liable node and RDN also follows the same procedure as between RON and RDN.

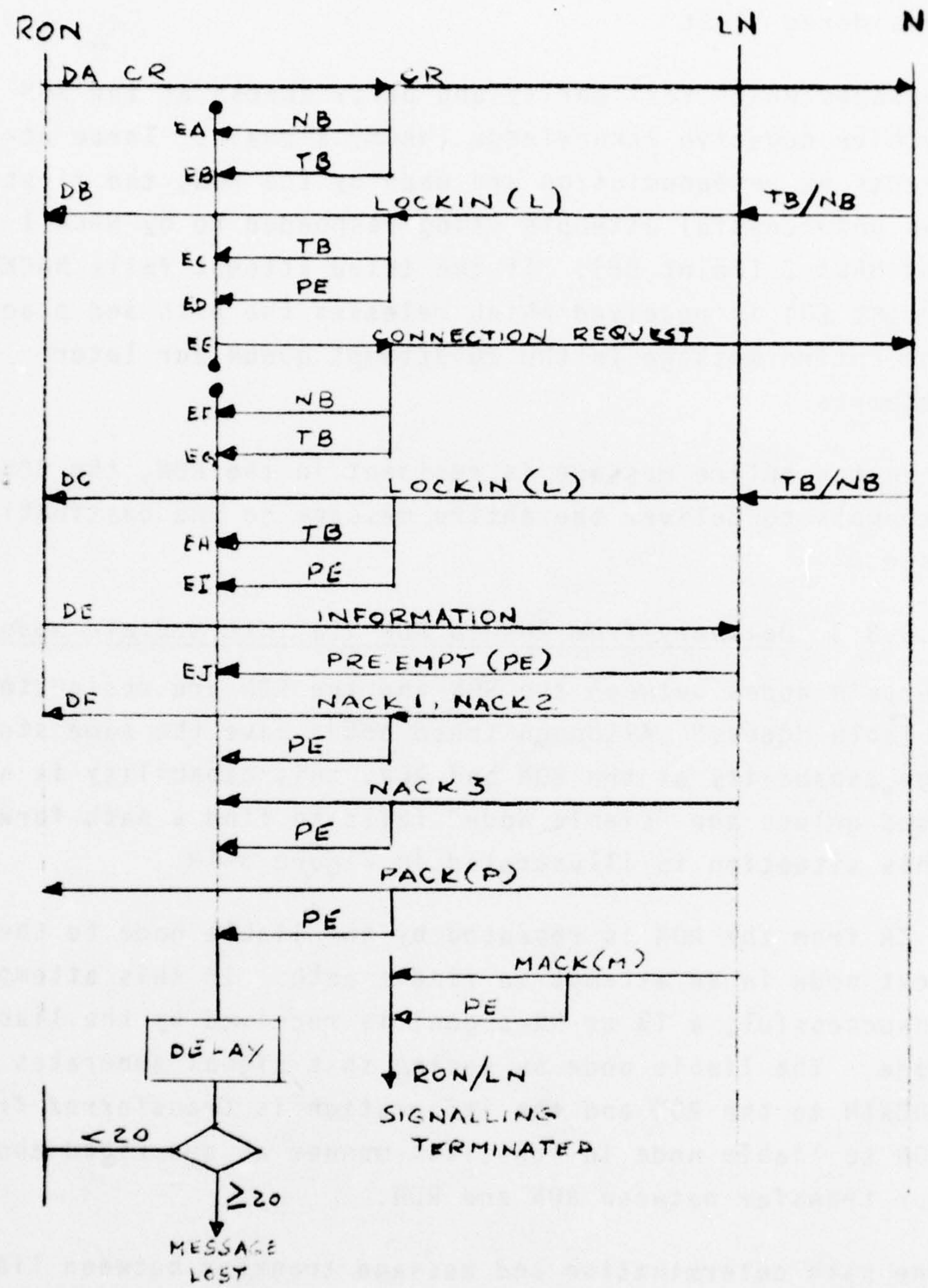


FIGURE 3-19 - SIGNAL FLOW BETWEEN RON & LN

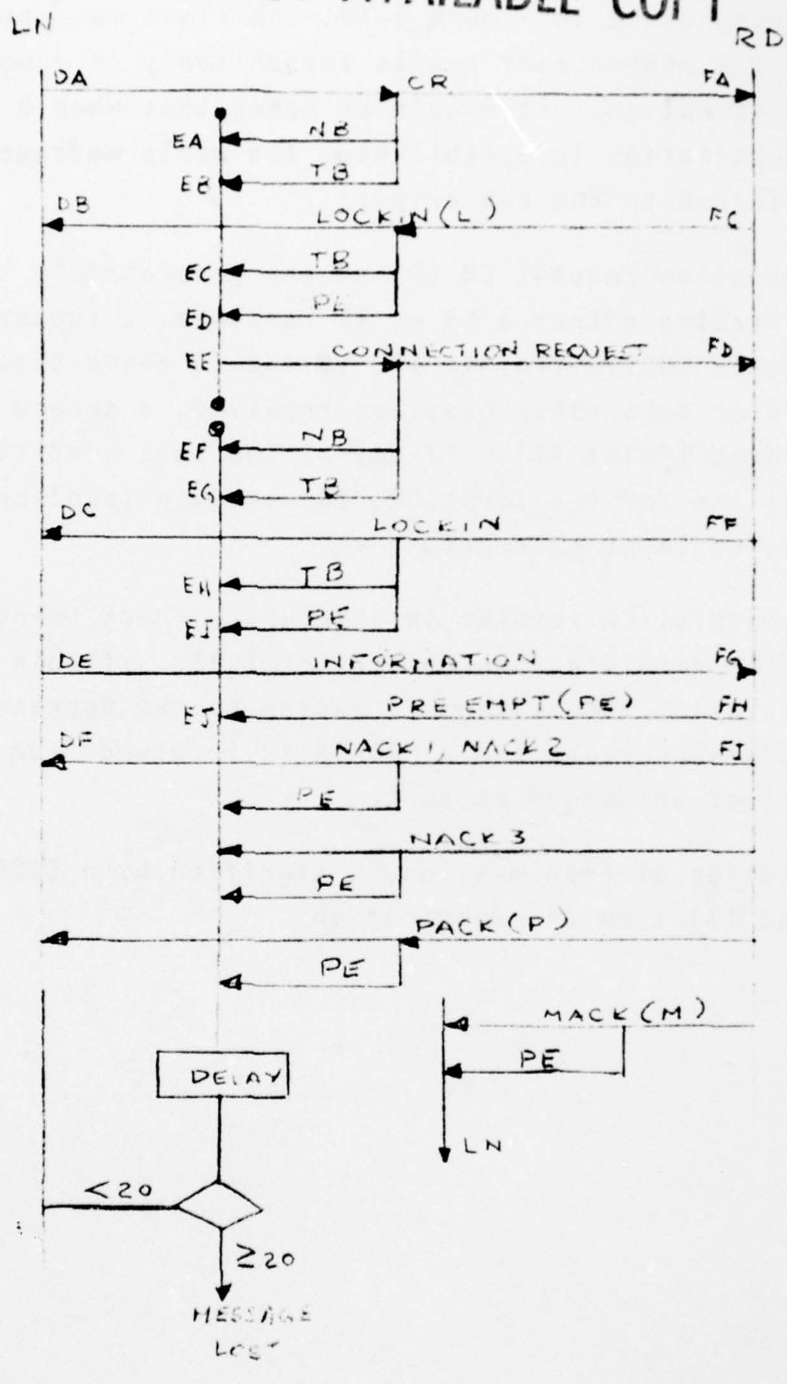


FIGURE 3-20 - LIABLE NODE TO RDN

3.3.3.4 Delivery To Destination

Referring again to Figure 3-18, the right hand portion shows the sequence of events for delivery of a message to the destination. It should be noted that when a route to the destination is established, the whole message is transferred to the subscriber.

A connection request CR (Point GA) generated by the RDN will receive either a NB or TB response, a subscriber busy or a LOCKIN (Points IA, IC and IB respectively). If NB, TB or subscriber busy are received, a second CR is generated (Point HF). If any of the same conditions prevail as for the first CR, the message is placed in a queue for later attempts.

A successful CR results in a security check being made with the receiving subscriber terminal. If this security check fails, the message is passed to the nearest compatible subscriber and a LOCKIN is received from either the first or second attempt.

Completion of transmission is signified by a DISCONNECT (Point II) from the destination.

4.0 CONSTRUCTION OF THE ADSS MODEL

4.1 INTRODUCTION

The ADSS model constructed for the simulation is designed with the following objectives:

1. To provide a basis to evaluate routing techniques and network types,
2. To service all message and call types using common facilities.

With this in mind, the model can readily be changed to produce empirically derived data using various network features. The variable network attributes are listed in Table 4-1.

In order to provide flexibility in the construction of the model, the program is segmented into four major modules which are the Traffic Generator, the Path Calculator, the Network Simulator and the Statistics Reporter. The interrelation of the modules is shown in Figure 4-1. The detailed submodules are depicted in the flow charts (see Appendix C, program description in program documentation).

The Traffic Generator is that unit which creates all traffic from inputs which reflect the user specifications pertaining to incident traffic; the output is the complete traffic set ready to enter the network. The path is determined for each message in the Path Calculator unit; where based on the routing technique an appropriate path is determined and the signaling message returned to the Traffic Generator. The message next enters the Network Simulator where message delivery is attempted. Upon termination of a run, the message proceeds to the Statistics Reporter which records anomalies occurring during the simulation and message transmit times in a form specified by the user.

TABLE 4-1

VARIABLE NETWORK PARAMETERS

1. Input Connectivity (for all nodes)
2. Link Capacities
3. Link Plex Type (Plex = simplex, duplex, or half duplex capability)
4. Node types (RN, RDN, ON, etc.)
5. Node Capacities
6. Node Function (type of switch - C/S, M/S, P/S, etc.)
7. Traffic Interarrival Time
8. Traffic Types
9. Priority Distributions
10. Security Distributions
11. Message Lengths
12. Routing Techniques
13. Network Types

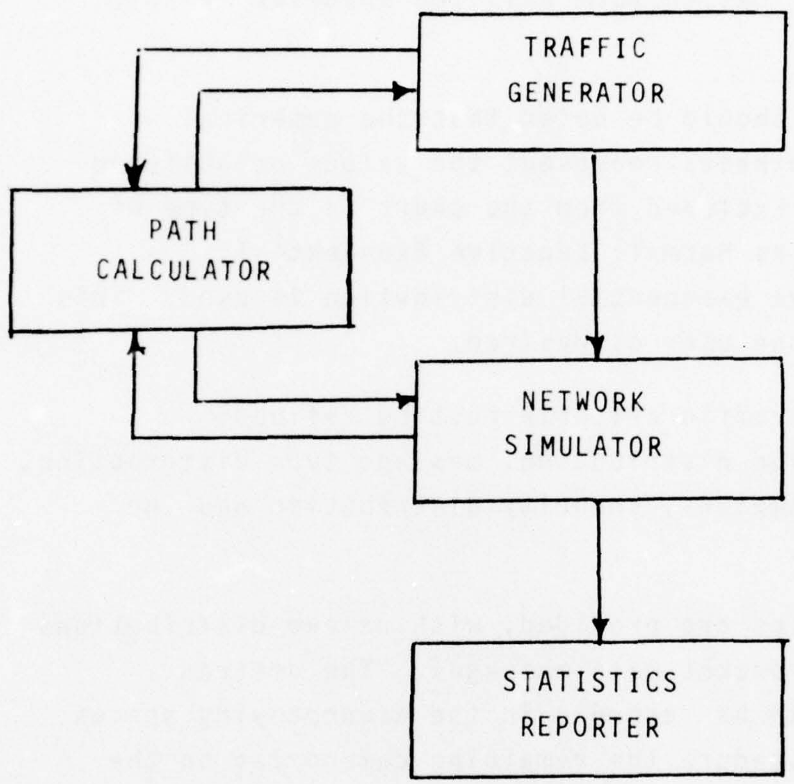


FIGURE 4-1 - STRUCTURE OF ADSS MODEL

4.2. MODULE DESCRIPTION

4.2.1 TRAFFIC GENERATOR

The function of this module is to create the incident traffic conforming to the user specifications. Table 4-2 represents a convenient specification form utilized whenever traffic is modified.

From Table 4-2, it should be noted that the numerical values in the parentheses represent the values established for the contract. Excluded from the chart is the type of distribution, such as Normal, Negative Exponential; presently a negative exponential distribution is used. This can be changed by the user as desired.

Fundamentally six traffic criteria must be defined: priority, destination distribution, message type distribution, message timing parameters, security distribution and the mobile subscribers.

Five priority classes are provided, with unique distributions for packet and non-packet data messages. The desired distributions should be recorded in the accompanying spaces. Continuing this procedure the remaining categories on the chart should be completed. Further instructions for the Traffic Generator modification can be found in the SNUG manual.[1]

Subsequent to generation, in the Traffic Generator portion of the model, the messages are then marked with specific data indicating message length, message type, originating and destination tributaries, priority, security, identification number and various parameters necessary to meet message formats. This information is stored in particular parameters locations within a transaction, as illustrated in Figure 4-2.

[1] Section G, CDRL-A004.

TABLE 4-2

TRAFFIC SPECIFICATION

A. Priorities

	Packets	%	Non-Packets	%
(High)	60	____(5)*	60	____(1)*
	50	____(0)	50	____(3)
	40	____(0)	40	____(15)
	30	____(0)	30	____(31)
(Low)	20	____(95)	20	____(50)
Total		100	Total	100

B. Destinations

	%
Local	____(26)
Adjacent Node	____(16)
Intra-Net	____(37)
Inter-Net	____(11)
Mobile Nets	____(10)
Total	100

C. Message Types

		%
Record - Single - Address Circuit-Switched	(RSACS)	___(27)
- Multiple - Address Message-Switched	(RMAMS)	___(13)
- Single - Address Message-Switched	(RSAMS)	___(13)
Voice - Two-Party Calls	(VTPC)	___(32)
- Conference Calls	(VCC)	___ (1)
Packet Data - Multiple Packets	(PDMP)	___(13)
- Single Packets	(PDSP)	___ (1)
	Total	100

* Parentheses reflect user specified quantity.

TABLE 4-2 (Cont'd.)

D. Message Timing

Voice Duration	- mean value (min.)		____ (4)*
	distribution		Neg. Exp.
Data Duration	- mean value (sec.)		____(10)
	distribution		Neg. Exp.
Percent of Record Traffic - 500 Line Blocks			____ (4)
Ratio of Data to Voice Traffic			%
	Data Traffic		____(67)
	Voice Traffic		____(33)
		Total	100
Traffic Origination Volume (erlangs)			____(.25)
Inter-arrival Time			Poisson

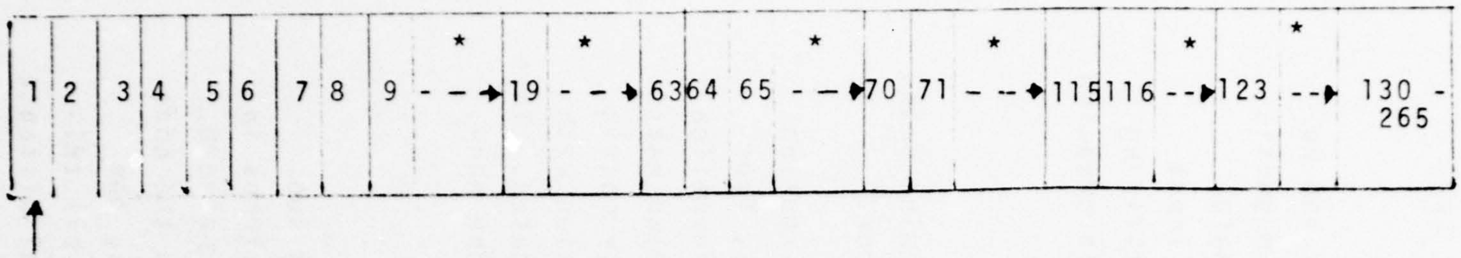
E. Security

			%
Special Category	(1)		____ (1)
Top Secret	(2)		____(4)
Secret	(3)		____(10)
Confidential	(4)		____(15)
Unclassified	(5)		____(70)
		Total	100

F. Percent Mobile Subscribers ____ (5)

---

* User Specified Quantity.



PARAMETER LOCATIONS

PARAMETER

1 Message length in Time Units
2 Message Type
3 Mobile Subscriber Flag
4 Message Identification Number
5 Responsible Regional Node
6 Origination Node
7 Beginning Node
8 Path Pointer
9 Destination Node
19 Starting in P9 (through P19) the path is stored (derived from Path Calculator)
63 Path Request Number
64 Multiple Message Identification
65 Originating Tributary Parameter Position in Path
70 RON
71 RDN
115 Parameter Position of RON(Indirect Address)
116 Parameter Position of RDN(
123 Time Message was Printed (Simulation Transaction generated)
130-255 NETSIM Path Storage

---

* Work Space

TRAFFIC GENERATOR MESSAGE SPECIFICATION FIELD

FIGURE 4-2

Prior to a transaction existing from the Traffic Generator, the Path Calculator furnishes the path (parameters P9-P19), after which a complete call/message exists.

Due to the model modularity the generated traffic can be imposed upon the Network Simulator or saved on a magnetic tape. Storing the traffic on tape enables meaningful comparisons in subsequent simulation runs, since input variation is eliminated. Another advantage of utilizing tapes is the subsequent elimination of CPU time in creation of traffic in future simulation runs.

4.2.2 PATH CALCULATOR

The Path Calculator is the unit required to determine paths for the Traffic Generator and the Network Simulator.

Since four routing techniques are available (two routing plans, each within a different network structure), four different Path Calculators are required. The information needed for each Path Calculator is structured in two matrix formats, the Directory matrix and the Connectivity matrix. The calculated path algorithm is used in conjunction with these each matrices to determine the route candidates. This algorithm is different for the hierarchical and the non-hierarchical models.

4.2.2.1 Connectivity Matrix

The Connectivity Matrix shown in Figure 4-3, is a two dimensional array where the number of rows and columns in the array is equal to the number of nodes in the network. The first element numbers in a row corresponds to the node numbers. Within a row in the Connectivity Matrix, the connection is ordered in a specific way. First, all tributary nodes that are adjacent to this node (nodal distance

Column 1 ... Column 17

Node #	CONNECTIVITY MATRIX																	
	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	
1	*	*	12	2	3	13	14	15	6	17	15	4	8	9	11	10	99	Row 1
	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	
2	*	*	5	6	12	1	3	9	13	14	17	15	4	8	11	10	99	
	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	
17	*	*	3	4	8	12	1	2	13	14	15	5	6	9	11	10	99	

Halfword Savevalue Location

Content of Halfword Savevalue

* Each row is right-justified, thus giving blanks in some rows.

CONNECTIVITY MATRIX - NETWORK 1

FIGURE 4-3

equals one) are placed in the row, followed by all the Regionals adjacent to this node. Next, all tributary nodes at a nodal distance of two, followed by all Regionals at a nodal distance of two are inserted in the matrix. Following these nodes, all tributaries and Regionals at a nodal distance of three are found, etc. This process is continued until all nodes are contained in this matrix. To indicate the end of a row, a '99' is contained in the matrix. For example, Node 1 is connected to Node 12 at a distance of one (no intervening nodes); Node 1 is connected to Nodes 2, 3, 13 and 14 at a distance of two (via Node 12).

4.2.2.2 Directory Matrix

The Directory Matrix shown in Figure 4-4, is utilized to obtain locations in the connectivity matrix. The directory stores the location of the first Regional at a given nodal distance, and last node at a given nodal distance. Additionally, the directory matrix stores information pertinent to the node type, responsibility and maximum nodal distance.

The unique features of the hierarchical deterministic path algorithm are:

1. The selection of responsible message switch and packet switch nodes.
2. Hierarchical routing criteria.

Since responsible regional nodes are assigned by the user, optimal paths are not necessarily generated. This results in the utilization of the "backbone" network, the criteria of which is a path exceeding two links.

The hierarchical routing criteria for the Deterministic and Adaptive Routing Technique (DART) is similar to that above. But the responsible nodes are selected by an algorithm

	XH[1] LOCATION OF LAST NODE WITH NODAL DISTANCE:							XH LOCATION OF FIRST REGIONAL WITH NODAL DIST.:						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	382	383	384	385	386	387	388	389	390	391	392	393	394	395
	622	626	630	634	635			622	625	630	634			
2	396	397	398	399	400	401	402	403	404	405	406	407	408	409
	641	646	648	651	652			641	645	648	651			
17	606	607	608	609	610	611	612	613	614	615	616	617	618	619
	895	897	902	906	907			-	897	900	906			

Context of Halfword Savevalue

Halfword Savevalue Location

Note (1) = Halfword Savevalue

DIRECTORY MATRIX - NETWORK

FIGURE 4-4

searching for the closest nodes possessing the required message function. A list of possible originating nodes is compared to the possible destination nodes in the selection of the responsible nodes. Finally, regional nodes are selected, if required, and the selected path is calculated.

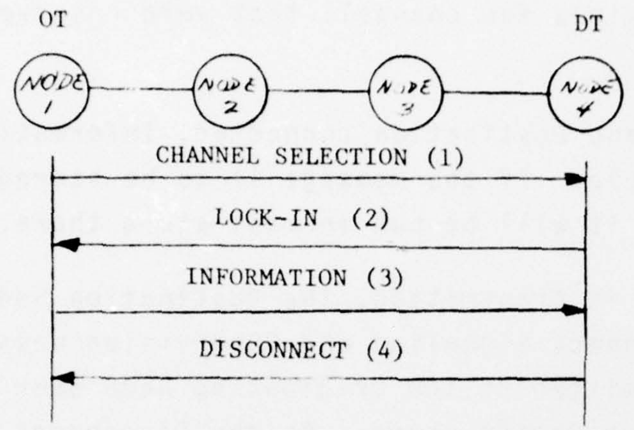
For the non-hierarchical routing techniques, regional nodes are eliminated, and an optimal path is calculated. The selection of responsible nodes is similar to the procedures described above.

4.2.3 NETWORK SIMULATOR

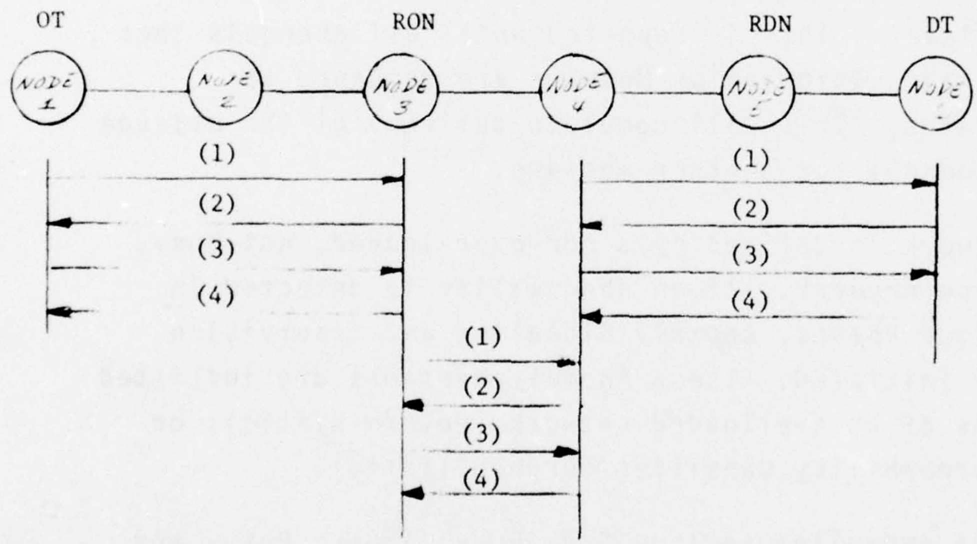
The Network Simulator (NETSIM) is the module responsible for traffic movement. Traffic enters the Network Simulator from the Traffic Generator module with its path and other information about itself. As the message moves through the network, it 'acts' as different types of messages; Control, Signaling and Supervision, and Information.

Delivering a message from an Originating Tributary to a Destination Tributary is accomplished by using four phases of message delivery; channel selection, lock-in, information transmission, disconnect. The same path is used in each phase. (See Figure 4-5.)

The Connection Request Signaling and Supervision message in Channel Selection reserves the channels that this particular message attempts to use. The signaling determines if the path and nodes are usable as the Signaling and Supervision message is transmitted from location to location. The Connection Request enters each node, the traffic level at that node is incremented. As the Connection Request attempts to leave a node over a signalling and supervision channel, it reserves an Information Channel to the next node on its path.



CIRCUIT SWITCH CONNECTION



STORE AND FORWARD CONNECTION

PHASE OF MESSAGE DELIVERY

FIGURE 4-5

Once Connection Request reaches the Destination Node, a Lock-in signal is transmitted back to the Originator Node. The Lock-in Phase acquires the channels that were reserved by Connection Request.

With the Origination and Destination connected, Information Transmission is possible. If the message is to be stored at the Destination Node, it will be put in mass store there.

After all information is transmitted, the Destination Node will initiate a Disconnect Signaling and Supervision message. This message is transmitted to the Originating Node over the same path that all Four Phases share. As the Disconnect message passes through a node in the path, it returns the related channel the Information Message used and decrements the traffic level. This is repeated until all channels that were used by this Information Message are returned to available status. This will complete delivery of the message and clear channels for another message.

A normal Network is defined by a non-over-loaded, not-busy, smooth running network. If an abnormality is detected in any of the Four Phases, Anomaly Signaling and Supervision messages are initiated. These Anomaly Messages are initiated by conditions of an overloaded network (Deterministic); or by defined probability densities (Probabilistic).

Deterministic anomalies include Node Busy, Trunks Busy, and Priority Bump. These all occur based on traffic levels in the network.

A Node Busy condition is sensed when the traffic level at a node is incremented beyond the defined Node Capacity. This Signaling and Supervision message can only occur in the Channel Selection Phase and is transmitted back to the

Origination Node. As the anomaly message moves through the network, reserved channels are freed and traffic levels are decremented.

Trunks Busy occur in the Channel Selection Phase when all information channels in the path are reserved and none of them are pre-emptable, i.e., used by a lower priority message than the one attempting connection. This anomaly message cancels reserved channels back to the Originating Node as it passes through the network.

Pre-emption can occur as the Lock-in message (which denotes the path is reserved for a call) acquires Information Channels that were reserved. By utilizing this reservation technique, a message cannot pre-empt a lower priority message until the higher priority message has reserved all needed channels from the Origination Node to the Destination Node.

Pre-emption can only occur in the Lock-In Phase, and the pre-empted message will initiate a Priority Bump Signaling and Supervision message. This anomaly message will return all channels that the pre-empted message used.

Probabilistic Anomalies include Subscriber Busy, Security Mismatch, and Nacks (Negative Message Acknowledgment). These are based on arbitrarily-specified random probability densities.

Subscriber Busy and Security Mismatch may happen in the Channel Selection Phase when Connection Request reaches the Destination Tributary. The probability of obtaining a Subscriber Busy is twice the Origination Traffic Density, which is presently .25 erlangs (P (Subscriber Busy) = 2 x 0.25 = 0.5). The probability of a Security Mismatch is based on the classification of each message; the higher classification the higher probability of an anomaly.

The NACK anomalies (NACK 1 thru 3) are based on a mathematical 'proneness' model. Given Nack 1, the probability of Nack 2 increases, and given Nack 2, the probability of Nack 3 increases.

The Nack 1 and Nack 2 Signaling and Supervision messages are transmitted to the Originating Node where the Information will be retransmitted. On Nack 3, the Information is not retransmitted but Signaling and Supervision is initiated to request an alternate path.

The three protocols, based on traffic types are Circuit Switch protocol, Narrative/Record Switch protocol, and Packet Switch protocol. Each message is handled under the guidelines of one of these protocols. Each protocol describes how a message is delivered, either Circuit Switched or under Store and Forward.

Circuit Switch protocol and Circuit Store and Forward protocol are two distinct ways in which a message is delivered to its destination.

The Circuit Store and Forward Traffic Handling Method is used in Narrative/Record Switching Protocol and Packet Switching protocol, while Circuit Switch protocol uses the Circuit Switch Traffic Handling Method.

Circuit Switch protocol attempts to circuit-connect the Origination Tributary (OT) to the Destination Tributary (DT). The Four Phases of Message Delivery are accomplished using a path, stored in the simulation transaction, representing the message. This path is used to simulate message movement from one node to the next.

In each message there is a pointer which indicates the location of the message in the network by pointing to

different storage compartments in the path string. These storage compartments contain the node numbers of the path. Therefore, by adjusting the pointer, a message moves in either direction along the stored path. Network travel is accomplished this way.

In the Information Transmission Phase of Circuit Switch Traffic Handling, the message is circuit switched from the Origination to the Destination without storing the message at any node along its path. By contrast, in Store and Forward protocol each message is normally stored at two points in the path string.

A message that must be stored in the network is transmitted from the Originating Tributary to its Responsible Originating Node. Only channels that are needed to get the message to the Responsible Originating Node are reserved and acquired. Once the Information reaches the Responsible Originating Node, the message is placed in mass storage. At the same time, it is queued for removal from the mass store, FIFO (First In, First Out) by priority.

After the message is removed from queue, a Connection Request attempts to connect the Responsible Originating Node to the Responsible Destination Node. If successful, the message is removed from the originating mass storage and transmitted to the destination mass storage. Note that transmission is circuit-switched through nodes connecting the two Responsible Nodes. At the Responsible Destination Node, when the message is placed in mass storage, it is queued for removal from the storage (FIFO by priority). If the Connection Request fails to connect the two Responsible Nodes, an attempt is made to transmit the message as far down its path as possible, to another node, (LN) Liable Node, capable of storing this message.

The message will be transmitted to a Liable Node (LN) in its path only if the Responsible Destination Node cannot be reached by a Connection Request and channels can be reserved to the Liable Node. In this way, the message gets as close as possible to its destination. The Liable Node stores the message and places it on queue to be transmitted to the Responsible Destination Node. Eventually, the message arrives at the Responsible Destination Node.

Removal from the queue at the Responsible Destination Node allows the message to complete the final segment in its journey to the Destination Tributary. A Connection Request reserves channels and the message is transmitted to the Destination Tributary where it is delivered to the subscriber.

4.2.4 STATISTICS REPORTER

The Statistics Reporter is the unit responsible for tabulating all data. Basically, the statistics are divided into two categories, input and output. On the input side tabular distributions are provided for all message categories. This includes representations of message lengths, message types, priorities, origination tributaries, destination tributaries, security and several more. These distributions are provided wherever traffic is generated by using the Traffic Generator unit. If an input tape is used, the distributions are not available.

The statistics available at the output include counts of anomalies, distribution of message times, and records of message movement. In order to determine the frequency of anomalies during a particular path attempt two tables are required. One table records anomalies which caused the message to be blocked (the message requests another path). Another table is required to record anomalies which caused the message to become lost (the message cannot be delivered

and is terminated). Since multiple path attempts are allowed two tables are allocated for each request. More tables are required for a larger number of attempts. An additional two tables are required to accumulate this data in order to provide an overview of the system. A total count of messages delivered and lost is provided in separate table.

Many other tables are required to maintain distributions of message times. In order to evaluate circuit switched messages independently of packet/narrative records; distribution of message call handling and call connection times are provided separately. Call connection time is defined as the time required from initiation of a call to the time the connection is complete. The call handling time is defined as the total time from initiation to termination minus the time of actual information transmission (call holding time).

Another time frequently used in table tabulations is total transmit time. Total transmit time is the time from call initialization to final termination. This data may be tabularized in any of seven categories. The categories are:

1. message/call length
2. message type
3. origination tributary
4. destination tributary
5. security
6. path length
7. priority.

Any two sets of tables may be tabulated in one run.

The time packet or narrative/record messages spend is a node may also be tabularized. The times of interest could be the total time a message is in a node from the time a message is

queued at a node. A total of five nodes for each time may be designated prior to a run; this selection of five nodes can be changed prior to each run.

A record of messages entering any of five designated nodes is provided when desired. The information contained within a record is:

1. a message identification number
2. time of entry
3. time of exit
4. time message was queued.

This record is user-defined as part of the program input.

Of the output statistics available, four have been of primary interest as criteria in evaluating routing techniques. Both call handling time and connection time measure system performance since the message length is not included in these times. This yields information dependent upon the routing technique and basic connection type (circuit switched protocol or store and forward protocol) which can be compared in subsequent runs. Another set of data, signaling and supervision queue times is an indication of service times at nodes. This information is presented in a tabular distribution for all nodes. A final set of statistics is provided in savevalues. These savevalues contain the number of total number of messages initiated, blocked, lost, and delivered at any time in the simulation. With this data a history of the messages connected may be obtained. The number of messages connected provides an indication of message throughput for the system.

The program structure was designed to be modular. For example, the source file for the simulation has an index tag starting in column 73 of every card. The digit in columns 75 has particular meaning in categorizing the modules.

Digits in the range of zero to three indicate common INPUT coding. This is essentially the Traffic Generator and initialization of the program. When column 75 contains a 4, the module is the Path Calculator. A value in the range of 5 to 6 indicates common NETSIM coding. And digits from 7 to 9 indicate unique NETSIM coding and the Statistics Reporter. This technique allowed the designer to quickly identify the software module and whether it was in a common area or one of the other major design modules.

Since several modules of the program, such as Path Calculator, have versions for each type of routing, another identification field is required. This field is contained in columns 73 and 74. This particular field is allowed the seven values defined below:

- 00 coding common-to-all programs
- 10 coding unique to hierarchical, deterministic program
- 20 coding unique to hierarchical, DART Program
- 30 coding unique to non-hierarchical, deterministic Program
- 40 coding unique to non-hierarchical, DART Program
- 13 coding unique to Deterministic Programs
- 24 coding unique to DART Programs.

Finally, in order to provide a standard terminology when discussing the programs, the following scheme is used:

SIGNALING/SUPERVISION ROUTING TECHNIQUE

	Deterministic	Dart
Hierarchical Network	1	2
Non-hierarchical	3	4

A program referred to as '1' is a Deterministic, hierarchical run.

A '4' is a DART, non-hierarchical run, and so forth for 2 and 3.

5.0 RESULTS OBTAINED

5.1 INTRODUCTION

As a result of the termination of a complete simulation run an immense collection of data has occurred. All the statistics specified in the Statement of Work are generated with the addition of particular statistical distributions used in the simulation analysis. The output is formatted in the standard GPSSV entities such as tables, queues and savevalues as shown in Figure 5-1 (a complete interpretation of the entities is provided in the GPSSV Users Guide).

The simulation statistics may basically be categorized into four types:

a. input traffic distributions
b. output traffic transit time distributions
c. blocking frequencies
d. unique time distributions.

A review of each category and the philosophy used in the tabulation follows in this section.

In the network analysis, the evaluation criteria has been divided into four parameters:

a. call-handling time
b. call connect time
c. signaling and supervision queuing time
d. statistics, relating to message traffic.

Since this data is of major significance the terminology is defined prior to the actual interpretation of the results, later in this section.

5.2 INPUT TRAFFIC DISTRIBUTIONS

Each incident message in the Traffic Generator is sorted into various traffic categories prior to entering the Network

TABLE BLFQ1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
251	3.350	1.878	841.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	84	33.46	33.4	66.5	.298	-1.251
2	22	8.76	42.2	57.7	.596	-.718
3	6	2.39	44.6	55.3	.895	-.186
4	0	.00	44.6	55.3	1.193	.345
5	139	55.37	100.0	.0	1.492	.877

REMAINING FREQUENCIES ARE ALL ZERO

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
4	4	.675	8		.0	120.750	120.750	74	3
5	2	.058	6		.0	14.000	14.000	75	
11	10	3.061	26		.0	168.384	168.384	82	10
12	25	6.209	155	45	29.0	57.290	80.727	83	24

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

FULLWORD SAVEVALUES

NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS	NUMBER	CONTENTS
95	820	96	382	97	578	98	489	101	86	102	63
103	184	104	21	105	47	106	38	107	92	108	18
109	22	110	45	113	8	114	3	115	7	116	2

SAMPLE GPSS, OUTPUT ENTITIES

FIGURE 5-1

Simulator in order to provide a statistical check on the input message distributions. The particular distribution name and an accompanying explanation is given in Table 5-1. Since this set of tables is created only when the Traffic Generator is fully utilized, the tables are not available if traffic is produced from the magnetic tape.

5.3 TRANSIT TIME DISTRIBUTIONS AND INPUT VARIABLES

Distributions of the total origin-to-destination delay (transit time) is provided at the completion of a simulation run as required in 4.4.1 of the Statement of Work. Due to the significant CPU time and storage required in table generation, a limitation has been imposed on the transit time table sets for any single run; at this point two is the limit.

The transit time distributions can be sorted into any two of the categories listed:

a. transit time versus message/call delay
b. transit time versus message type
c. transit time versus origination tributary
d. transit time versus destination tributary
e. transit time versus security level
f. transit time versus path length
g. transit time versus priority level

Each category has twenty tables allocated to transit time distributions. This implies that a maximum of forty tables are devoted to transit time distributions. The procedure to change a table set and a review of the interpretation of results is found in the SNUG manual. (See Appendix G, program documentation.)

The 'table versus transit time output designation is defined in G-2. The tables will be collected for output of the program runs.

5.4 BLOCKING FREQUENCY DISTRIBUTIONS

A means of comparing the occurrence of various anomalies during each path attempt and routing technique has been arranged by utilizing the table entity. These counts are formatted into a set of tables which sort the anomalies and categorize the results; blocked or lost message. The tables used are numbers 61 through 68 for the Deterministic routing techniques and numbers 85 through 94 for the DART routing techniques. A listing of the tables, their titles, and a brief description of the data gathered is found in Table 5-2.

As an example of a table, refer to the Table BLFQ1 at the top of Figure 5-1. Within this table, the entities of concern are the entries in the table, the upper limit column, and the observed frequency; the remaining headings are of little significant value. In this particular table, BFLQ1, (Blocking Frequency - First path attempt) the entries in table reveals the total number of messages finding a blockage on the first connection attempt. The two remaining columns give the reason and relative frequency for the blocking. Reading down the "upper limit" 1 is an "observed Frequency"

Table #	Title	Description
41	ORIGN	The distribution of messages vs the originating tributaries.
42	INTVS	The interarrival time distribution for all voice messages.
43	INTDT	The interarrival time distribution for all data messages.
44	MDIS1	The message (type) distribution prior to creation of multiaddress messages.
45	RSLIT	The data message (type) distribution.
46	LENVC	The voice message length distribution (in time units).
47	RNGEX	The narrative/record message (type) distribution.
48	PNGEX	The packet message (type) distribution.
49	LENDT	The data message length distribution (in time units).
50	CLASS	The security classification distribution/ or all messages.
51	PRITY	The priority level distribution for all messages exceeding packet messages.
52	PRITP	The priority level distribution for the packet messages.
53	DESTP	The distribution of messages to the various destination node types.
54	DESIN	The distribution of messages to the individual destination nodes.
55	MDIST	The distribution of total incident traffic to the message types.
56	MOBSB	The message (type) distribution whose destinations are mobile subscribers.

INPUT TRAFFIC DISTRIBUTIONS

TABLE 5-1

AD-A047 644 RCA GOVERNMENT COMMUNICATIONS SYSTEMS CAMDEN NJ F/G 17/2

ADVANCED SIGNALING/SUPERVISION AND ROUTING STUDY.(U)

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TABLE TITLE	TABLE #	DESCRIPTION OF CONTENTS
		Deterministic
DELST	(61)	Total number of lost and delivered messages.
LTCL1	(62)	Count of causes for lost calls on first path attempt.
LTCL2	(63)	Count of causes for lost calls on second path attempt.
LTCL3	(64)	Count of causes for lost calls on first and second path.
BLFQ1	(65)	Count of causes for blocked calls on first path attempt.
BLFQ2	(66)	Count of causes for blocked calls on second path attempt.
BLFQ3	(67)	Count of causes for blocked calls on first and second path.
OMRTM	(68)	Count of second path attempts requested, and count of messages returned for temporary storage due to blocking conditions.
		DART
DELST	(85)	Total number of lost and delivered messages.
LOST1	(86)	Count of causes for lost call on first path attempt.
LOST2	(87)	Count of causes for lost call on second path attempt.
LOST3	(88)	Count of causes for lost call on third path attempt.
LOST4	(89)	Count of causes for lost call on first, second, and third path attempts.
BLKD1	(90)	Count of causes for blocked call on first path attempt.
BLKD2	(91)	Count of causes for blocked call on second path attempt.
BLKD3	(92)	Count of causes for blocked call on third path attempt.
BLKD4	(93)	Count of causes for blocked call on first, second and third path attempts.
STR23	(94)	Count of second, and third path attempts and messages returned for temporary storage due to blocking conditions.

ANOMALY TABLES

TABLE 5-2

of 84 meaning 84 messages were blocked due to the subscriber being busy. The "Observed Frequency" of 22, associated with "Upper Limit" 2 indicates 19 messages were blocked due to pre-emption, but they were re-transmitted. "Upper Limit" 3, "Observed Frequency" 6 means 6 messages had to obtain a different path due to the successive Negative Acknowledgments. Since the "Observed Frequency" was zero for "Upper Limit 4, no messages were blocked due to node capacity. Finally, "Upper Limit" 5, "Observed Frequency" 139 indicates 193 messages were blocked due to the unavailability of trunks.

This style of interpretation is repeated for the remaining tables; Appendix I contains a key to the interpretation of the tables and all the anomaly tables generated in the study runs.

The Table PRIO is maintained for each simulation run in order to gain an insight to the priority scheme, by counting the messages of each priority level being pre-empted.

5.5 UNIQUE TIME DISTRIBUTIONS

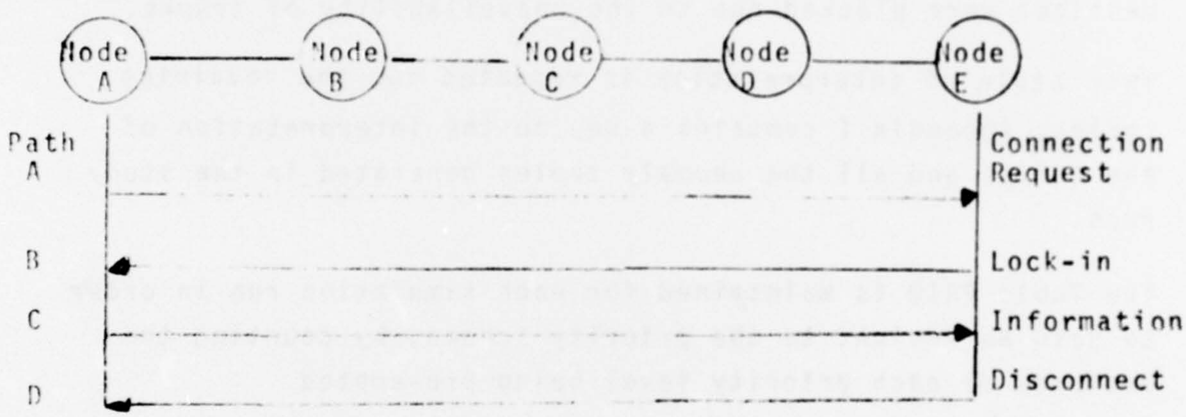
Two sets of tables remain to be described, those generating statistics on the time messages are queued at nodes and the total time a message is at a node. In each case, the nodes of concern must be selected by the user with a limit of five nodes per case. The procedure to specify the particular nodes of interest is described in the SNUG manual.

The "Nodewatch" tables provide a distribution of the total time, this includes signaling/supervision queuing, PNR queuing and processor delay messages encountered at the nodes. Table 76 through 81 are used for this purpose with table 81 presenting the accumulation of the previous five tables. The remaining table set spans tables 71 through 75 while providing a distribution of the times PNR messages are queued at a responsible node.

5.6 EVALUATION CRITERIA

Due to the enormous amount of data available, a thorough weighting and analysis of all the output is highly difficult and beyond the scope of the project. With this in mind, consultation with RADC has produced a set of parameters to be used in comparing alternate routing schemes. The following is a discussion of the evaluation criteria and message philosophy involved.

5.6.1 CALL-HANDLING TIME



Simplified Message Phase Diagram

Figure 5-2

The first evaluation parameters, Call-Handing Time represents the total time required by a call independent of the actual information duration. This time is graphically illustrated in Figure 5-2 as the total time required to traverse Paths A, B and D. Call-Handing Time is of significant value since it represents the time devoted by the network in a message setup and tear-down. But of equal importance, this factor gives an indication of the trunk sizing since it includes signaling/supervision and PNR queuing times. This accounts of the significance time differences between circuit-switched and store/forward message types. It should be noted call-handling is encountered even for lost calls since a portion

of processor and network time is involved in attempting a connection.

5.6.2 CONNECT TIME

The second measurement parameter, Connect Time represents the total network time expended in establishing a connection from end to end. In Figure 5-2, connect time represents the time required to traverse Paths A and B, while in the real world it corresponds to the time from the completion of a dial sequence until the actual ring tone occurs. Both connect time and call-handling time are tabulated distinctly for circuit-switched and store/forward messages in order to provide a meaningful basis of comparison.

A logical inference from the term connect time is that time exists only for messages actually receiving a lock-in signal. The major differences between connect time and call-handling time is the time required for a disconnect to occur and the time a PNR message is queued. Therefore, in the circuit-switched case, the difference between the times is due to disconnect signaling. This time can be used in obtaining an estimation of path lengths.

5.6.3 SIGNALING/SUPERVISION QUEUE TIMES

All queuing encountered by messages occurs to either signaling/supervision messages or the PNR messages at responsible nodes. The queuing times are accumulated separately for S/S and PNR messages as shown in Figure 5-3; through these times an indication of the network loading can be obtained.

5.6.4 MESSAGE/CONNECTED STATISTICS

In order to provide a relative simple comparison and a measure of network throughput several traffic related ratios

QUEUES

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
4	7	.154	73		.0	15.547	15.547	74	
5	5	.428	83		.0	37.939	37.939	75	
11	9	1.108	94	1	1.0	86.712	87.645	82	
12	9	.507	1800	488	27.1	2.072	2.843	83	

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

PROGRAM 1

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
4	7	.447	284		.0	16.517	16.517	74	
5	6	.781	155		.0	52.851	52.851	75	
11	6	1.023	78	1	1.2	137.512	139.298	82	
12	10	.362	2071	678	32.7	1.832	2.725	83	

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

PROGRAM 2

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
4	7	.154	89		.0	15.460	15.460	74	
5	5	.227	95		.0	21.284	21.284	75	
11	15	3.054	139		.0	195.510	195.510	82	1
12	9	.404	1900	559	29.4	1.895	2.686	83	1

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

PROGRAM 3

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
4	7	.382	265		.0	14.807	14.807	74	
5	6	.672	140		.0	49.307	49.307	75	
11	7	1.293	80	1	1.2	165.924	168.025	82	
12	11	.277	1487	438	29.4	1.916	2.716	83	

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

PROGRAM 5

FIGURE 5-3 - S/S AND PNR QUEUE STATISTICS

are calculated at constant time intervals and outputted. The format being used in the output is illustrated in Figure 5-1 - SAVEVALUES: the specific data format is listed in Table 5-3. (Note: All percentage savevalues are multiplied by ten, i.e., a context of 578 is interpreted as 57.8%).

A delivered message is considered to be a normally completed call; a blocked message is a call which could not be connected or completed and will be re-transmitted; and lost calls are those which are terminated prior to completion of the call. The algorithm used is the calculations, divides the total messages of each particular category by the appropriate network population. The network population is maintained by incrementing a particular savevalue whenever a message enters and decrementing the savevalue when a message terminates. The numerator is obtained by maintaining separate counts of the blocked, delivered and lost messages of the appropriate message category. Terminated and delivered counts are incremented only once for each message, but the blocked count is incremented each time a message encounters a blocking condition. It is for this reason a summation of the blocked, lost and delivered ratio must be avoided (the result is often greater than 100).

From this data, graphs can be prepared, Figures 5-4 through 5-14, represent the system status at various times. This information is beneficial when evaluating alternate routing schemes since similar curves can be drawn on a single graph allowing rapid visual comparisons.

TABLE 5-3

Savevalue	Contents
X95	Time calculation was performed (in simulated time units)
X96	% of voice messages delivered
X97	% of CS-Data messages delivered
X98	% of PNR messages delivered
X99	% of voice messages blocked
X100	% of CS-Data messages blocked
X101	% of PNR messages blocked
X102	% of voice messages lost
X103	% of CS-Data messages lost
X104	% of PNR messages lost

Message/Connected Statistics - Savevalue Format

5.7 RESULT DISCUSSION

5.7.1 CALL-HANDLING AND CONNECT TIMES

A representation of the connect time required by circuit switched messages is found in Figure 5-4. Due to unstable conditions the first eight simulated minutes of all graphs will be disregarded in discussions, after this time the curve appears to stabilize. At this point the results indicate relatively equal connection times for the hierarchical and non-hierarchical routing techniques. The time difference between these two routing categories is slight once it is recognized three seconds are required in the hierarchical techniques to travel to the regional, obtain the path and return to the originating tributary. Therefore, the path calculating algorithm yields equivalently optimal paths

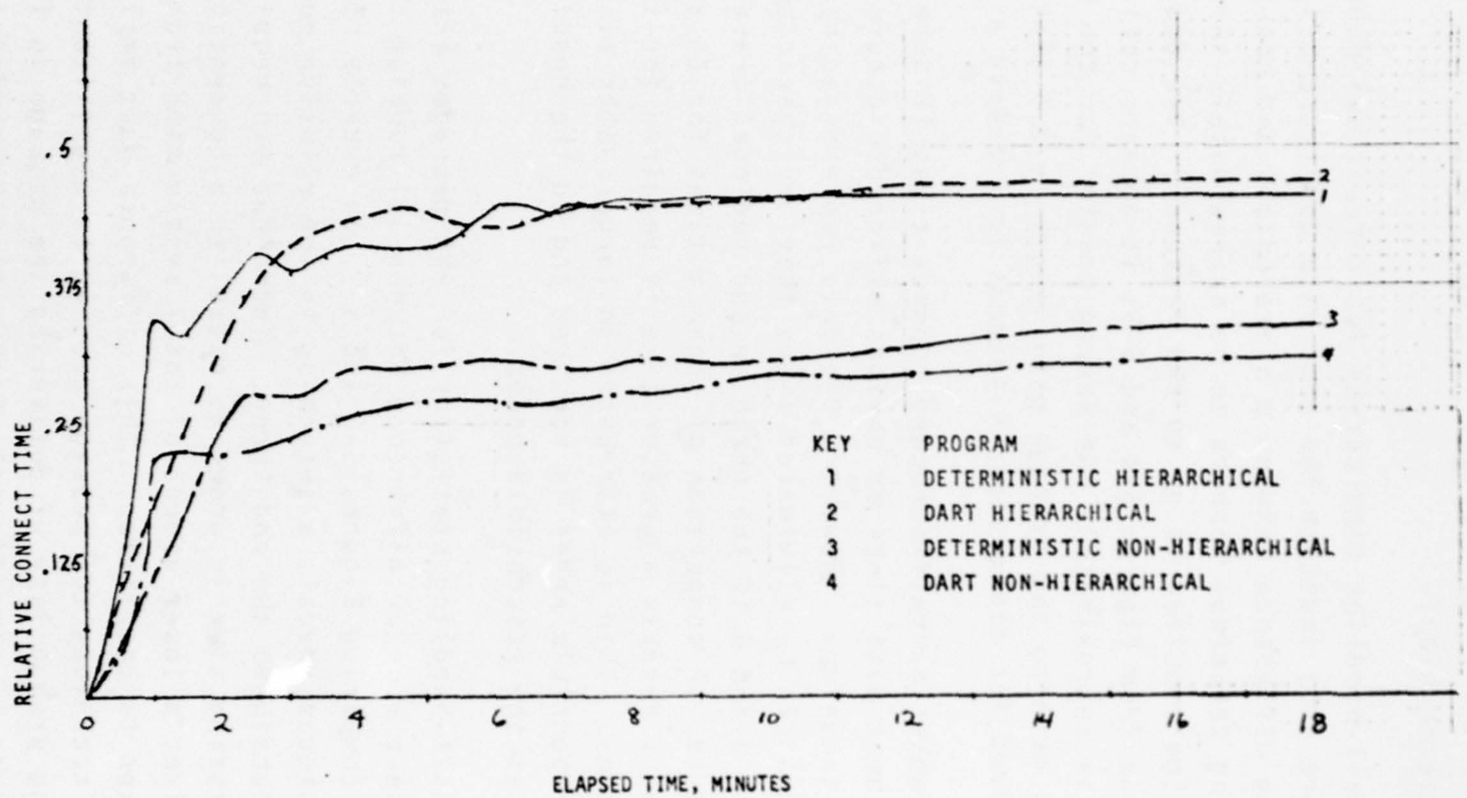


FIGURE 5-4 STUDY RESULTS CONNECT TIME CIRCUIT SWITCH PROGRAMS 1-4

whether the circuit-switch routing is hierarchical or non-hierarchical.

The call-handling time curves for circuit switched messages (Figure 5-5) indicate the same data as Figure 5-4, the timing difference between a hierarchical and non-hierarchical routing technique appears to be approximately three seconds, the time required to go to the regional. One deduction can be made from Figures 5-4 and 5-5; it appears call-handling time is approximately one second greater for the hierarchical case, meaning the average path length is 2.5 links (1 second required for disconnect/.4 seconds to traverse a link).

The packet-narrative/record connect times (Figure 5-7) display pertinent data since an obvious difference occurs between each technique. However, the data represented by curves one and two can be eliminated since they are characterized by curves 3 and 4 if the three second regional travel time is included. A comparison of connect times for CS and PNR messages reveals a greater time is required for the later messages. This is attributed to larger paths since travel to responsible nodes is required and to the queuing occurring at the responsible nodes.

The call-handling statistics for PNR messages (Figure 5-6) indicate a major difference between all routing techniques. Upon comparing Figures 5-6 and 5-7, an orderly ranking of techniques reveals a switching in the relative positioning of techniques two and three. Technique two requires more processing time in order to establish a connection, but it requires a lower amount of total system time from initialization to completion. This difference must imply that in a DART technique the message queuing is significantly smaller or the probability of delivering the message in fewer path attempts is significantly higher than Deterministic. An

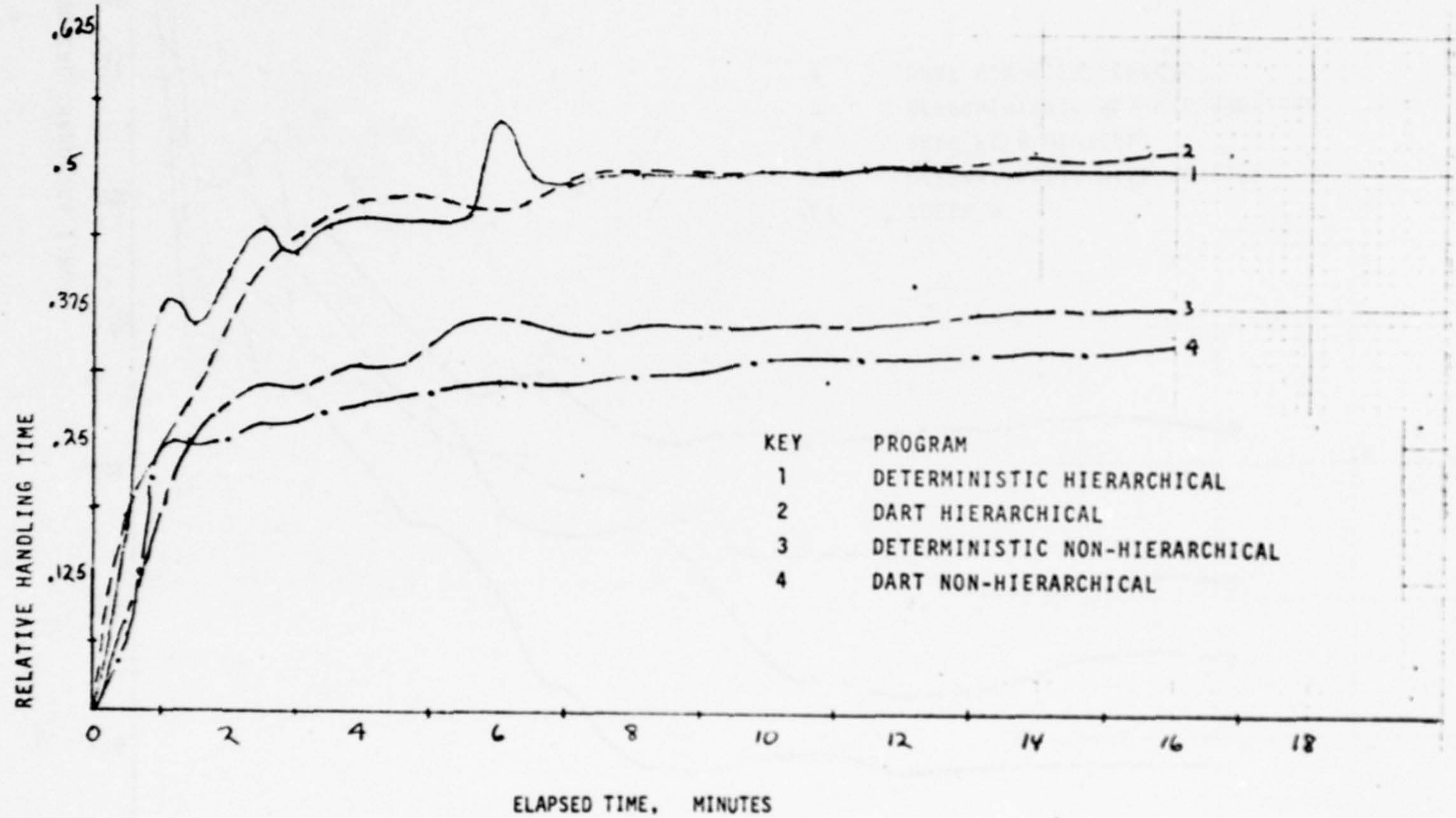


FIGURE 5-5 STUDY RESULTS CALL HANDLING TIME CIRCUIT SWITCH PROGRAMS 1-4

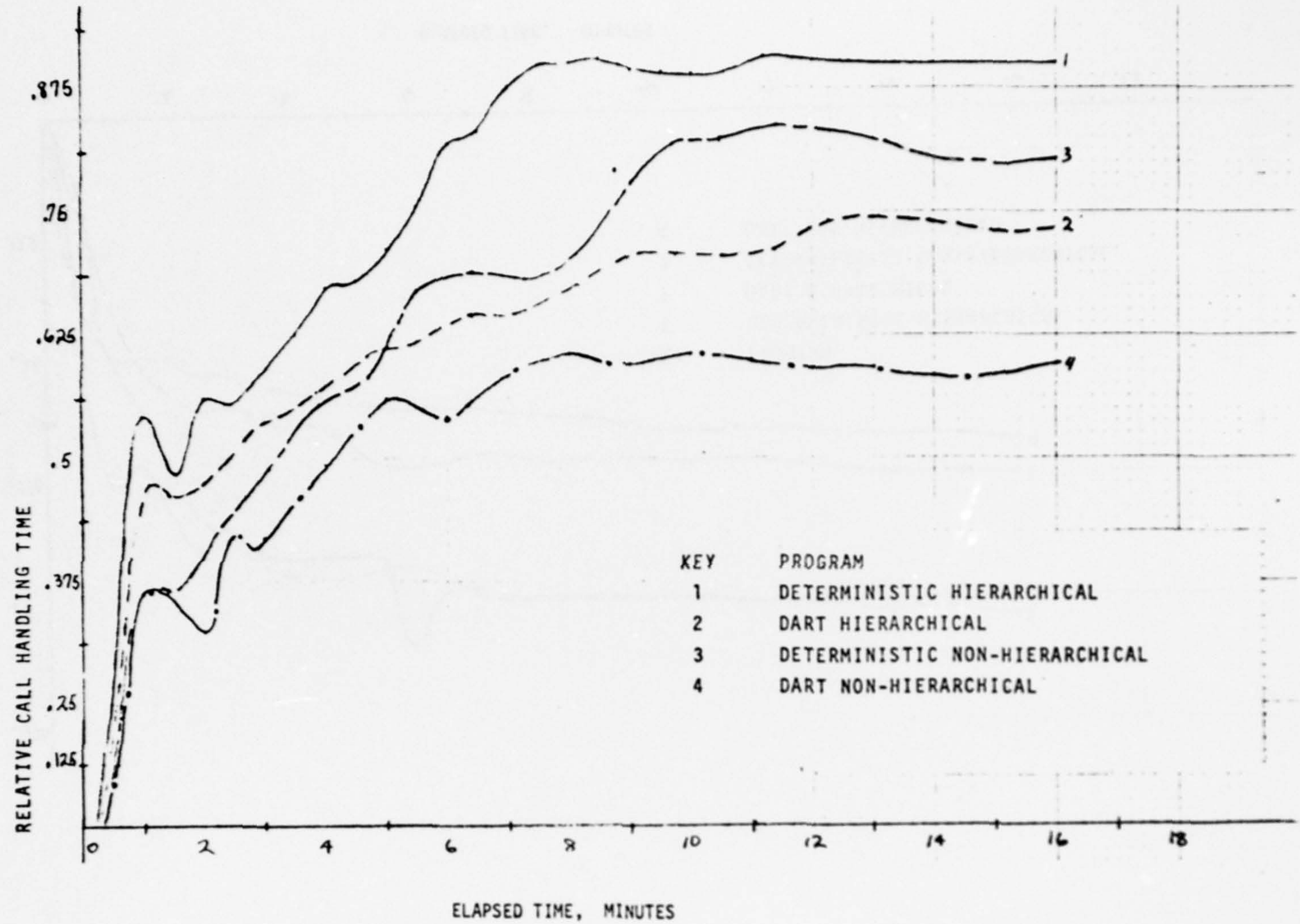


FIGURE 5-6 STUDY RESULTS CALL HANDLING TIME PNR PROGRAMS 1-4

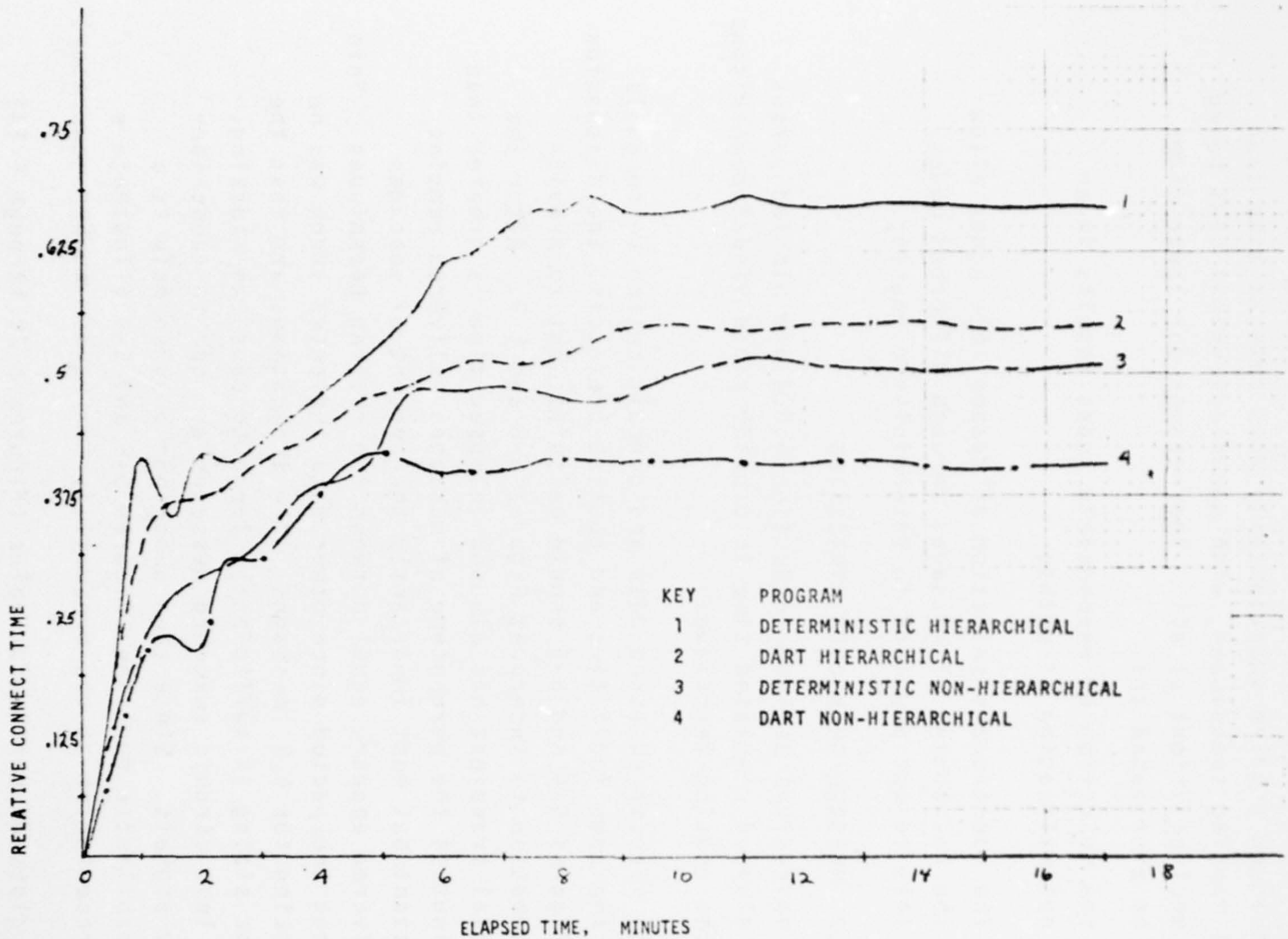


FIGURE 5-7 STUDY RESULTS CONNECT TIME PNR PROGRAMS 1-4

overall conclusion reveals both Deterministic routing techniques require substantially more network time than DART routing techniques, with non-hierarchical DART being the most efficient of all. The reasons for lower times can be attributed to:

a. the selection of responsible nodes results in an optimalization of paths;

b. The spontaneous selection of responsible nodes allow the re-routing of messages through different nodes. This is not possible in Deterministic routing.

5.7.2 MESSAGE/CONNECTED STATISTICS

The savevalues defined in Section 5.6.4 are plotted versus the elapsed simulated time to provide rapid visual comparisons of the routing techniques.

Since circuit switched data and circuit switch voice calls use the same facilities and routing protocols, the discussion of Figures 5-4 and 5-5 should be sufficient to provide information to interpret Figures 5-8 and 5-9. After the initial transient has elapsed (elapsed time is greater than 8 minutes) the percentage of messages delivered remains constant but most importantly the percent of messages delivered appears equal between the routing techniques. This is not unexpected since other data indicated there was no blocking for C.S. messages. The indications are that the trunk sizing is sufficiently large to cause no blocking, all lost circuit switched messages are due to subscriber busy signals. Since the subscriber busy anomaly is a probabilistic function, Figures 5-8 and 5-9 illustrate a representation of the probability (or random number generator).

The plots of particular value (Figures 5-10 through 5-14) represent the status of PNR messages. Again the rate of

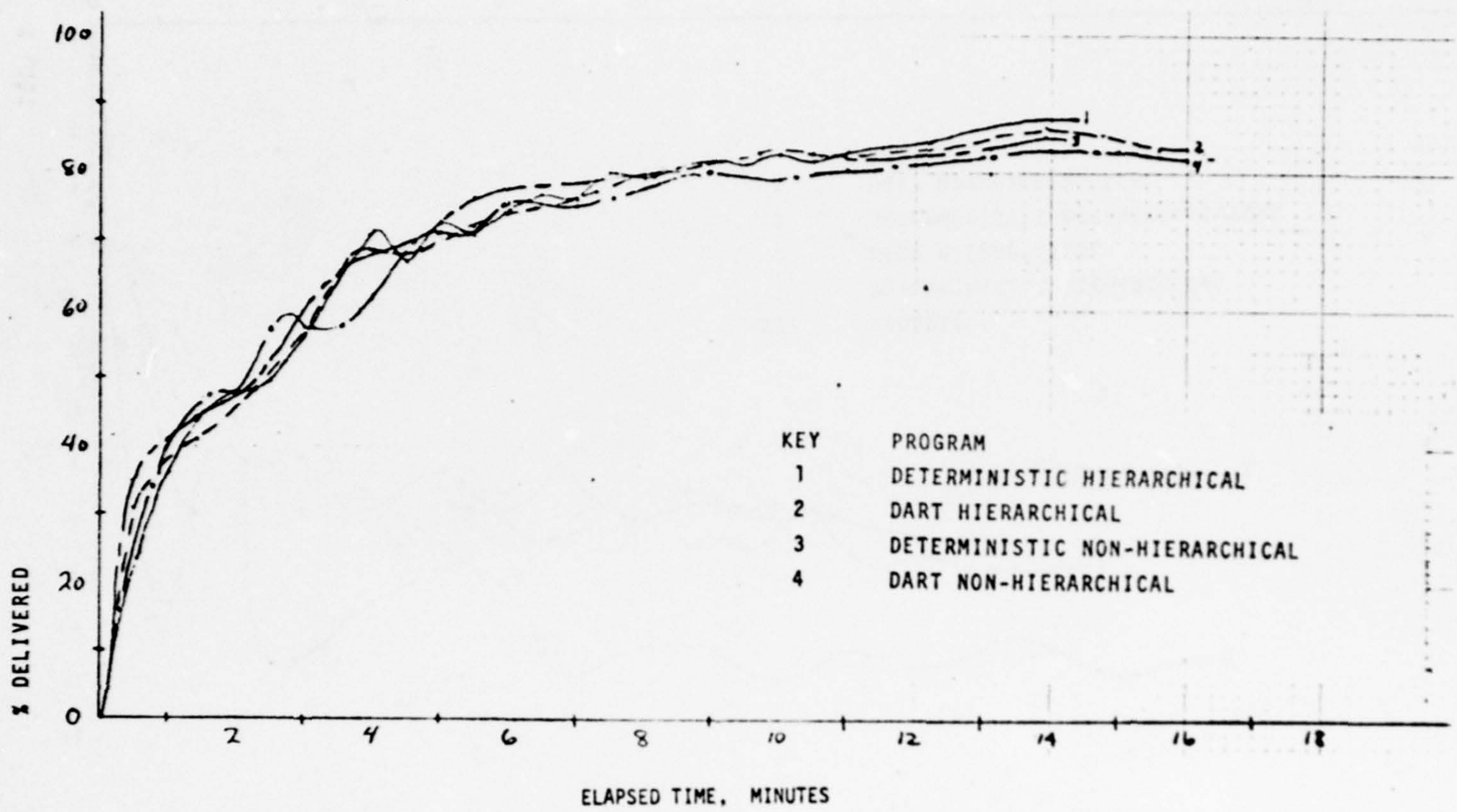


FIGURE 5--8 STUDY RESULTS % DELIVERED CIRCUIT SWITCH PROGRAMS 1-4

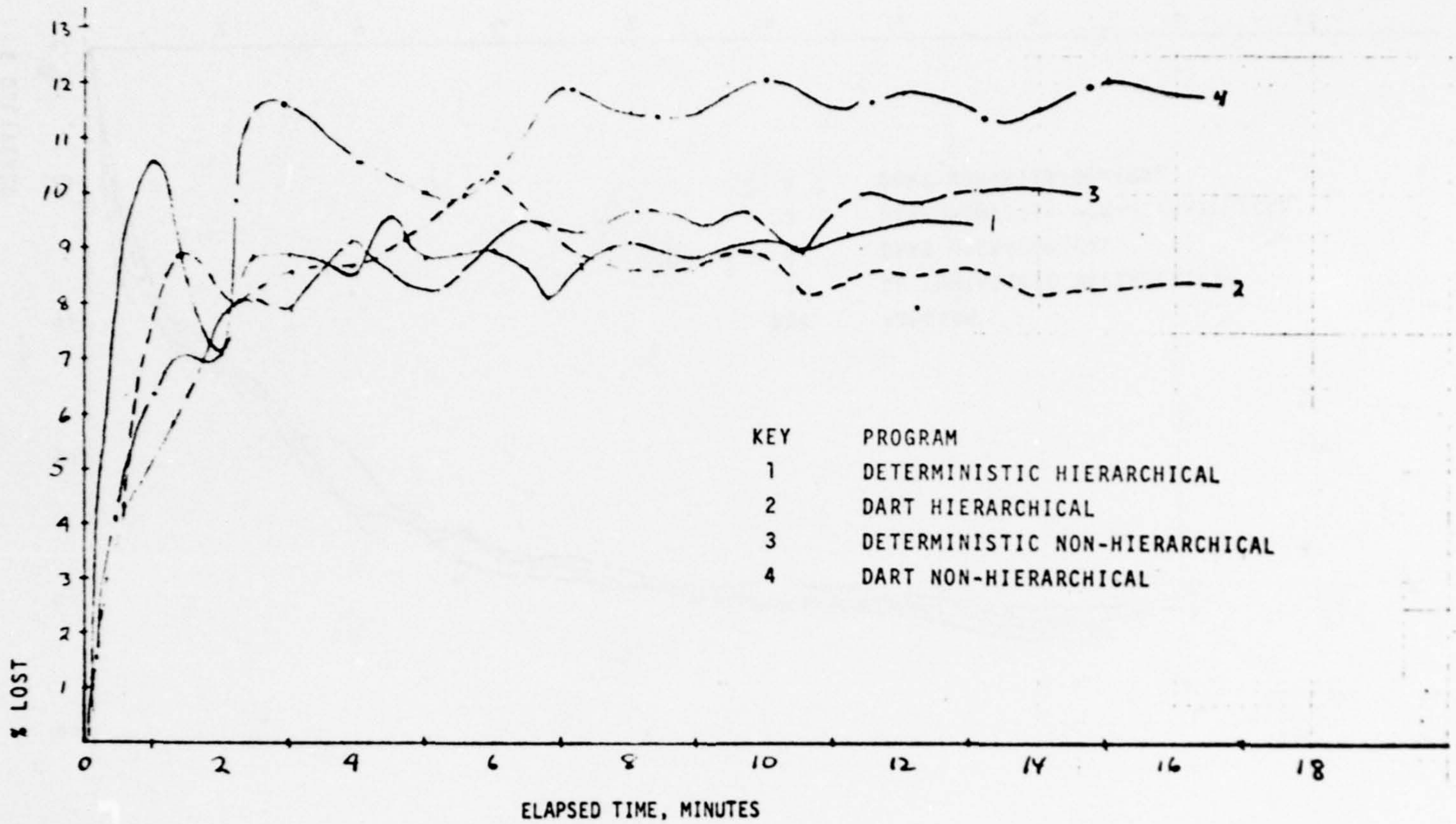


FIGURE 5-9 STUDY RESULTS % LOST CIRCUIT SWITCH' PROGRAMS 1-4

delivered to current network messages seems to be relatively constant at approximately 85%. Due to the proximity of the four curves, an obsolute judgment of the best routing technique is not possible from this data.

Figure 5-13 presents the relative number of blocked messages for each routing technique. Techniques 1 and 3 indicates a relative higher number of blocked messages as opposed to techniques 2 and 4; this is apparently due to responsible nodes. The Deterministic routing techniques use assigned responsible nodes at all times. Therefore if trunks are unavailable into a particular responsible node, the re-routing simply causes the message to reach that node through a different path, the node must still be utilized. However, the DART technique has the ability to select different responsible nodes if it is blocked, this should result in fewer blocked messages. This might only be a temporary state or due to the fact the responsible nodes are building queues causing more "live" messages in the system but a relative constant rate of messages being processed. Therefore, the system population (or the denominator) is increasing while the numerator is constant or increasing at a slow rate.

Figure 5-14 represents data supporting the earlier premises, since more messages are queued in deterministic techniques, fewer are receiving lost call signals. This results in a relative lower percentage of lost calls. But the throughput of the DART technique is higher causing lower queuing and more messages being terminated. Due to the fixed subscriber busy function and the relative high percentage of local traffic a substantial number of the lost messages are due to a busy on a local connection (approximately 50-60% of the 12% lost messages may be attributed to this).

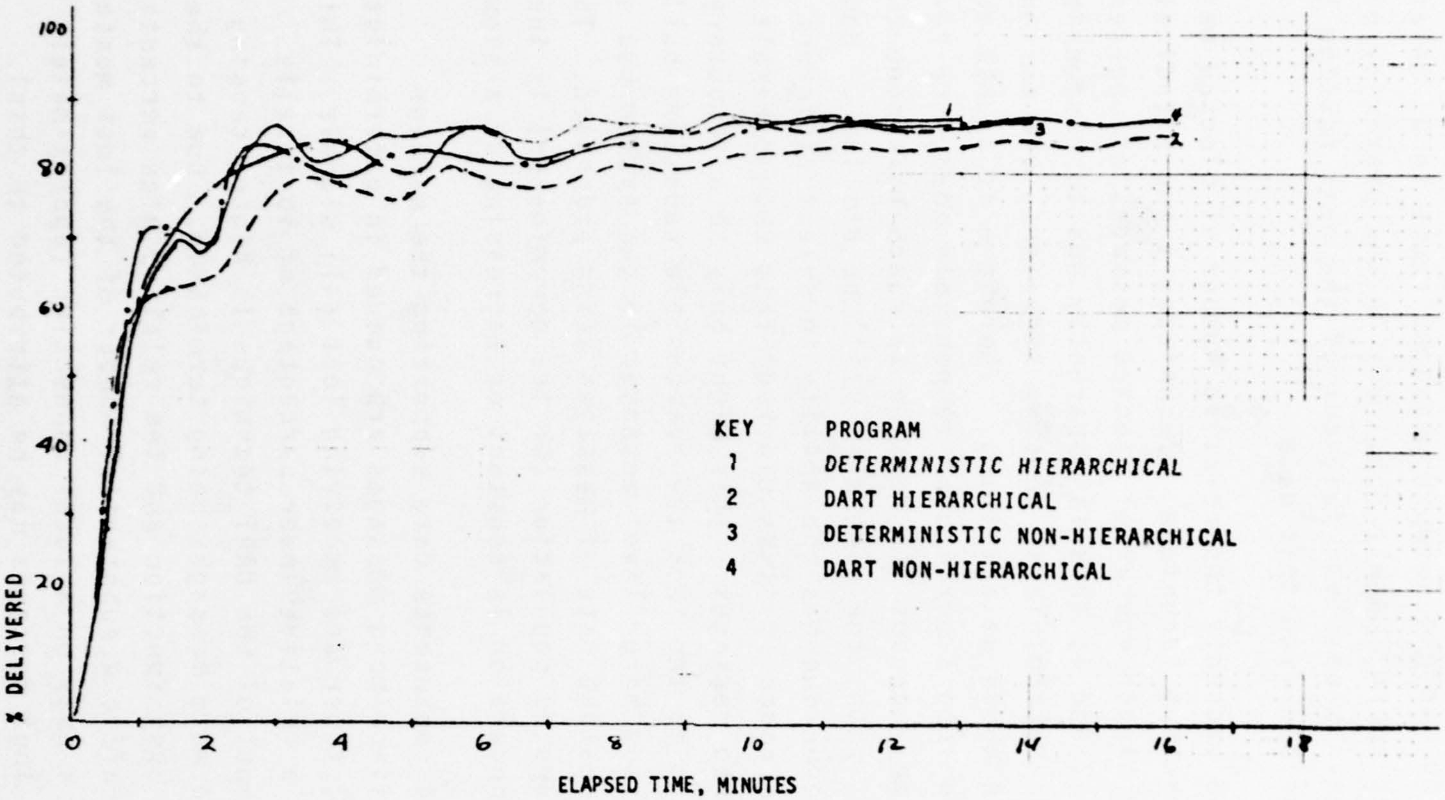


FIGURE 5-10 STUDY RESULTS % DELIVERED DATA PROGRAMS 1-4

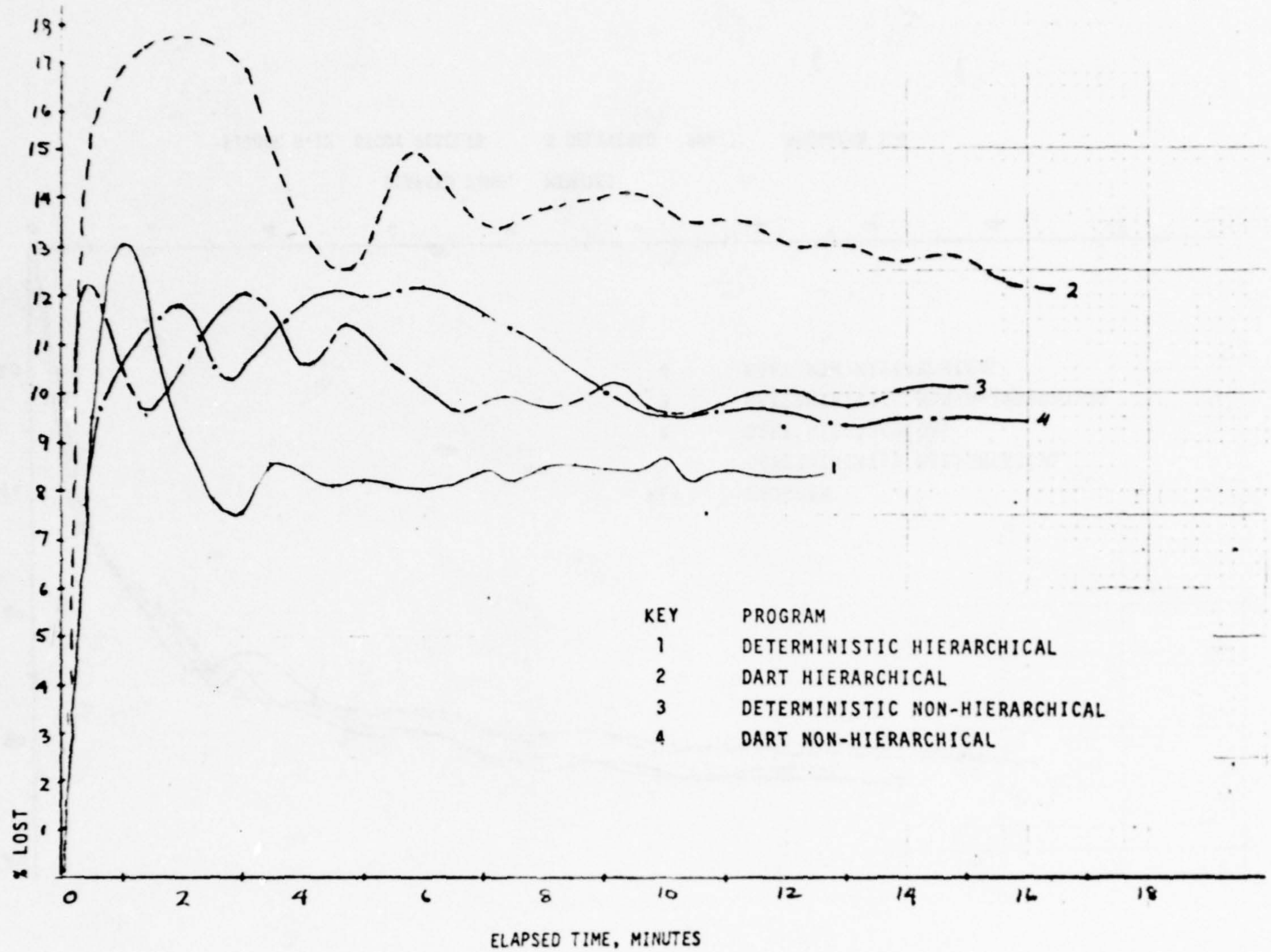


FIGURE 5-11 STUDY RESULTS % LOST DATA PROGRAMS 1-4

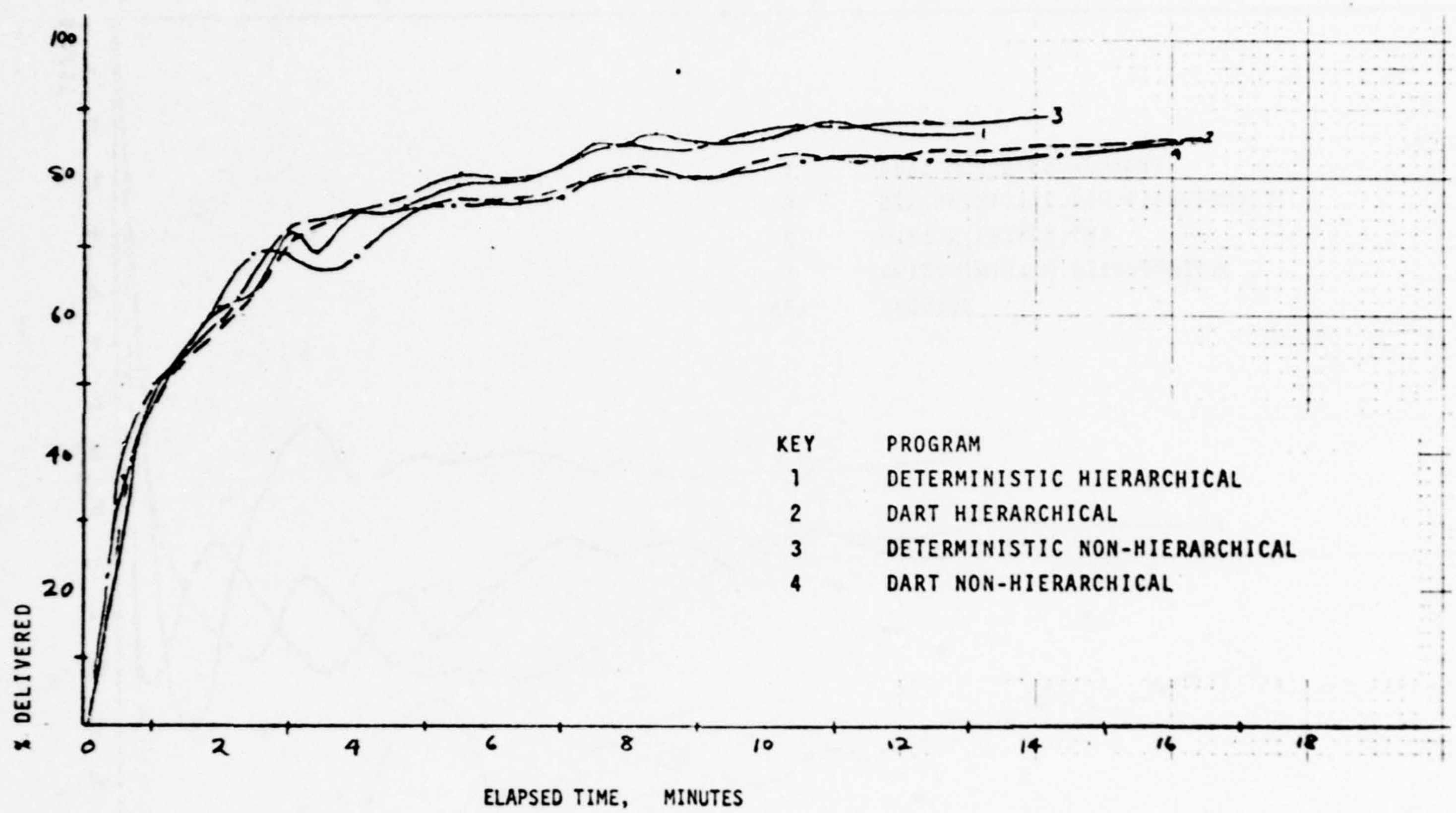


FIGURE 5-12 STUDY RESULTS % DELIVERED PNR PROGRAMS 1-4

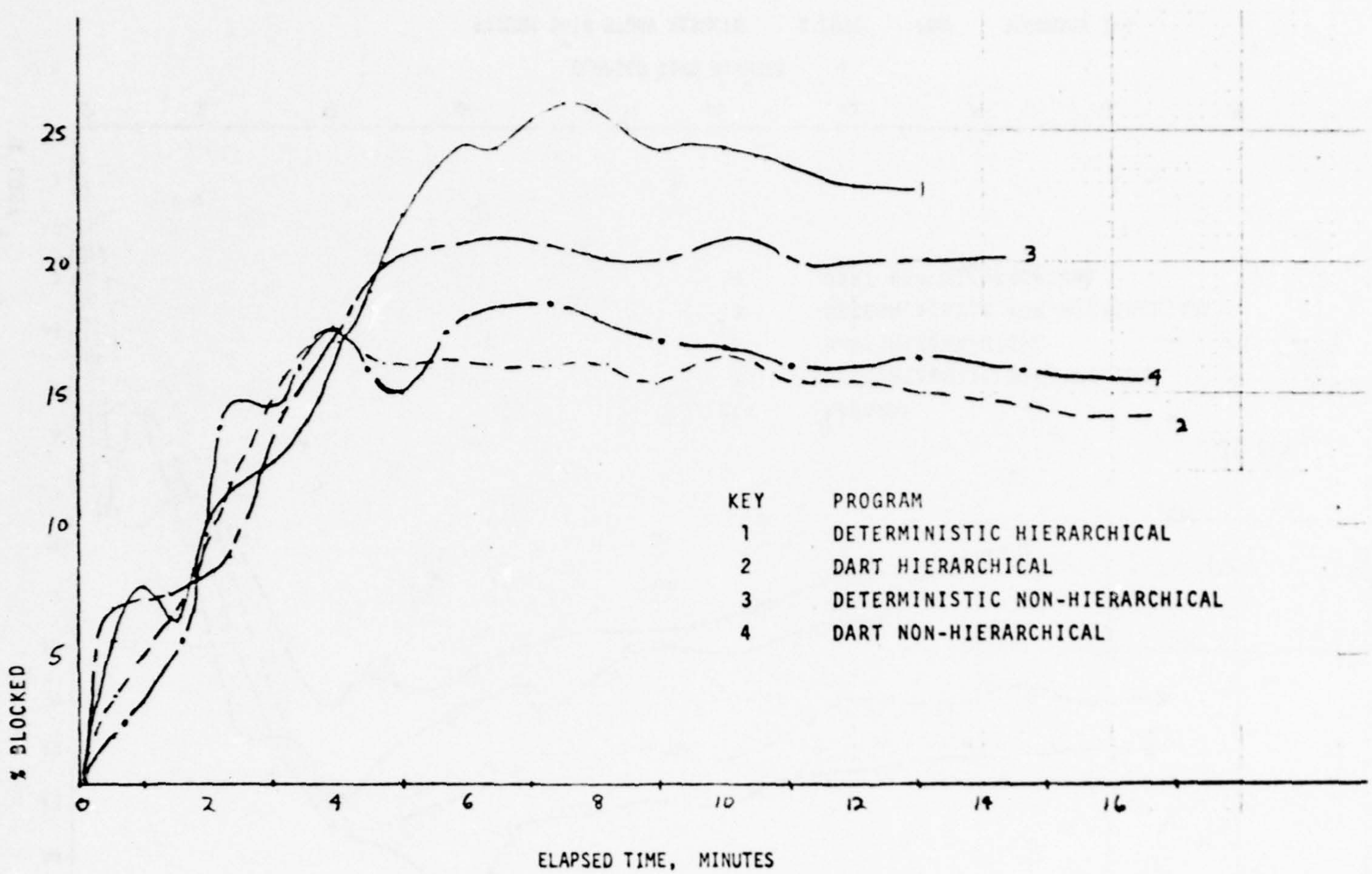


FIGURE 5-13 STUDY RESULTS % BLOCKED PNR PROGRAMS 1-4

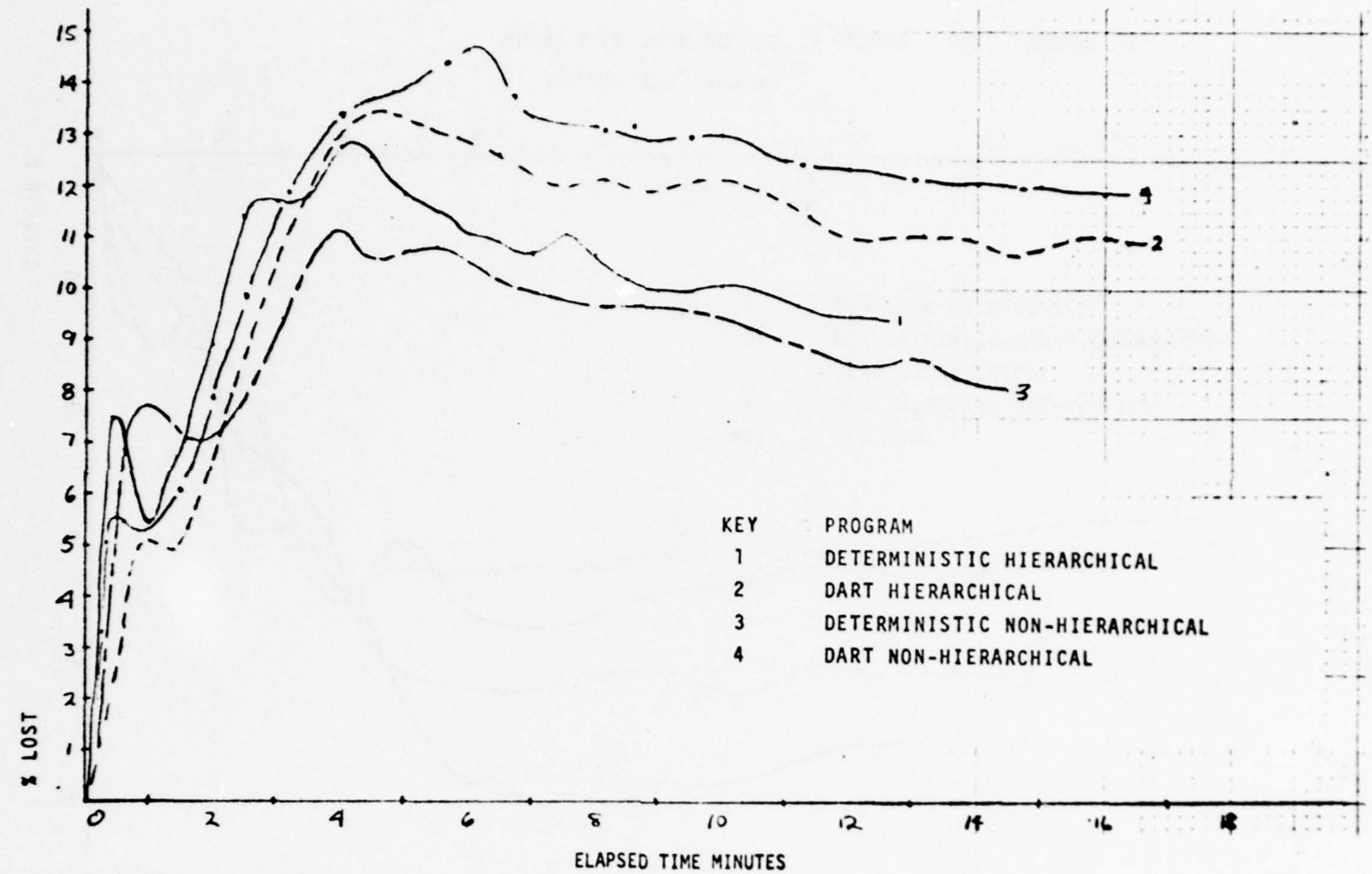


FIGURE 5-14 STUDY RESULTS % LOST PNR PROGRAMS 1-4

6.0 STUDIES

6.1 REFINEMENT OF ROUTING SCHEMES

6.1.1 INTRODUCTION

The following relates the simulated routing schemes to the more practical aspects of the real world.

A simulation model has the capability of moving only one transaction (message) at a time through the model and the actual output of the simulation is a series of time-related events which give an indication of the message handling capability of the network.

In designing the simulation model, one of the inputs is the protocol of the routing scheme, i.e. the philosophy behind the direction a message takes in passing through the network from point of origin to destination. These protocols are indeed related to the real world conceptually, however, certain characteristics not used in the simulation require specification before a routing scheme can be used in an operational network.

These characteristics are:

a) The format and content of the messages which pass between nodes for moving a message.

b) The type and amount of storage required in the routing tables at each node.

c) The format and content of messages required to initially compose the routing tables and to update the tables to reflect changes in the network which may occur due to damage or to reconfiguration. (Network control messages)

It is to these three characteristics that the following section is addressed.

6.1.2 DESCRIPTIVE NETWORK

Figure 6-1 shows the network which will be used for descriptive purposes in describing the routing technique characteristics.

This network is actually a subset of the network used in the simulation but so configured as to allow description of the many cases which might occur during the routing of circuit switched, message switched and packet switched traffic deterministically or by DART (Deterministic and Adaptive Routing Technique) when the network is either hierarchical or non-hierarchical.

In the descriptive network, all nodes have circuit switching capability but only nodes C and E have message switching and packet switching capability while at the same time being designated as "Responsible" nodes, a term which will be further explained in the elaboration of the routing plans.

The terms hierarchical and non-hierarchical as applied to the network define in general the inter-responsibilities of the nodes in traffic handling.

In the non-hierarchical sense all nodes have equal capability as far as traffic handling is concerned.

In the hierarchical network, the regional nodes feature as the most powerful in the network in that they store maximum routing information while at the same time providing access to and egress from the backbone network which under certain conditions of the routing plans becomes a preferred route

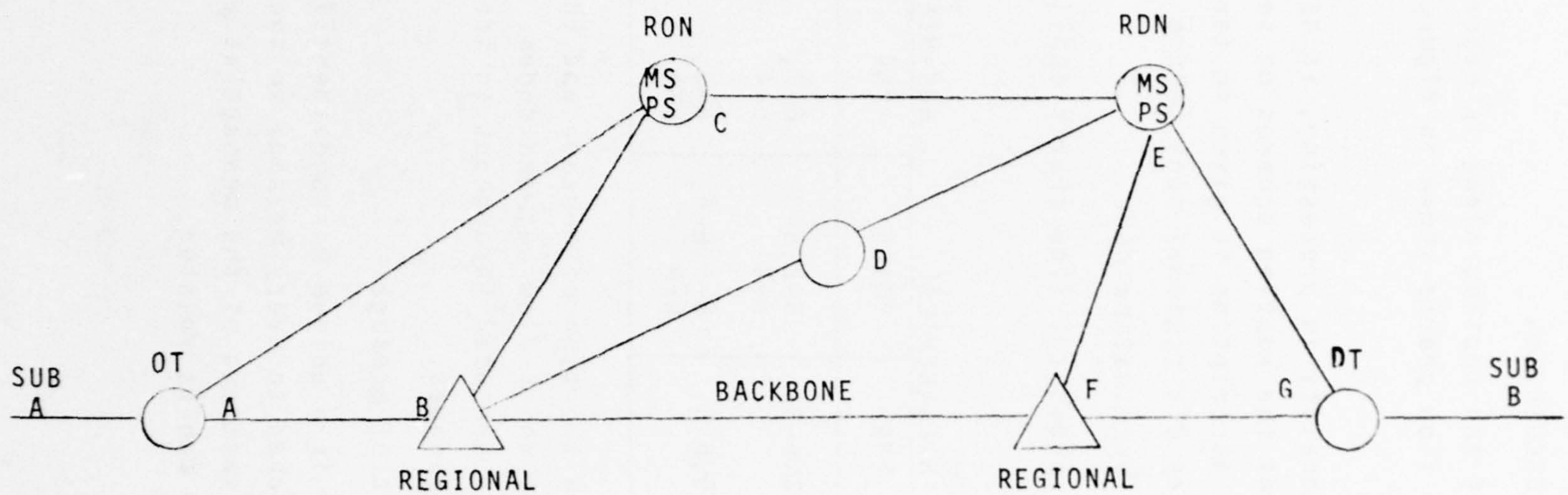


FIGURE 6-1 - NETWORK SUBSET

for messages.

6.1.3 FLOW CHART DESCRIPTION

The mechanization of the routing plans is described through a series of flow charts shown in Figures 6-2 through 6-8.

Because of the commonality in processing, it has been possible to represent the routing schemes on seven charts. Each routing scheme description is given in terms of the originating tributary OT, regional node (where applicable), and intermediate or terminating node.

The following table shows the flow charts applicable for each routing scheme.

	HIERARCHICAL		NON-HIERARCHICAL	
	PNR	VOICE	PNR	VOICE
DART	6-2,6-3,	6-2,6-3 6-4	6-7, 6-4	6-7,6-4
DETERMINISTIC	6-5,6-6,	6-5,6-6, 6-4	6-8, 6-4	6-8,6-4

The flow charts show the type of message and the message content for messages which flow between nodes. The following abbreviations are used throughout to identify the characters in the messages.

SOM - start of message.

IDENT - this is a unique message identifier attached to every message so that all transactions of the message at any node can be related.

SECY - this is the security designation of the calling subscriber.

PRI - is the priority of the current message entered by the calling subscriber.

TYPE - this character indicates the type of message (voice, message switched, packet switched) which is to be handled.

SUB A - this is the identifier of the calling subscriber.

SUB B - this is the identity of the called subscriber.

RTE - this is the identification of the determined route by node number.

EOM - is the end of message designator.

LI - this is the character unique to a LOCK-IN message.

RR - this character is sent from tributary to regional on an initial request for a route.

ARR - this character is sent from tributary to regional on a request for an alternate route.

BUSY - this character is sent in a response to a routing message when an ATB is encountered at any point in the route.

OUT - this character is sent in a response to a routing message when a trunk outage is encountered at any point

in the route. It is always accompanied by the node number which cannot be accessed.

CR - this character is an indicator that a connection request is being made.

6.1.4 ROUTING TABLES AND TRUNK HUNTING

In the flow charts certain blocks are labelled "OT or REGIONAL DETERMINES ROUTE". The method of route determination is by selecting trunks assigned to the adjacent node in the table and the adjacent node is specified in the route determined at the point of origin. The originating node must therefore include listings of the full internode connectivity and since all nodes can be considered as originating nodes with respect to the subscribers local to that node, the full network connectivity must be resident at all nodes.

The routing tables in each node would thus consist of a listing of the nodes to which it is connected and a listing of the trunk or trunks giving access to these nodes. Thus, the routing plan would require a trunk hunting scheme in order to select the required trunk. Since the protocol includes a five level priority scheme trunk hunting will be arranged to select a trunk of lower priority than that specified in the message if pre-emption is necessary. This requires that in each trunk hunt the trunk with the lowest priority must be recorded in the initial hunt and selected if all trunks are busy.

6.1.5 ROUTING MESSAGE CONTENT

The characters required in the various routing messages are given in Section 6.1.3 and the actual messages are given in

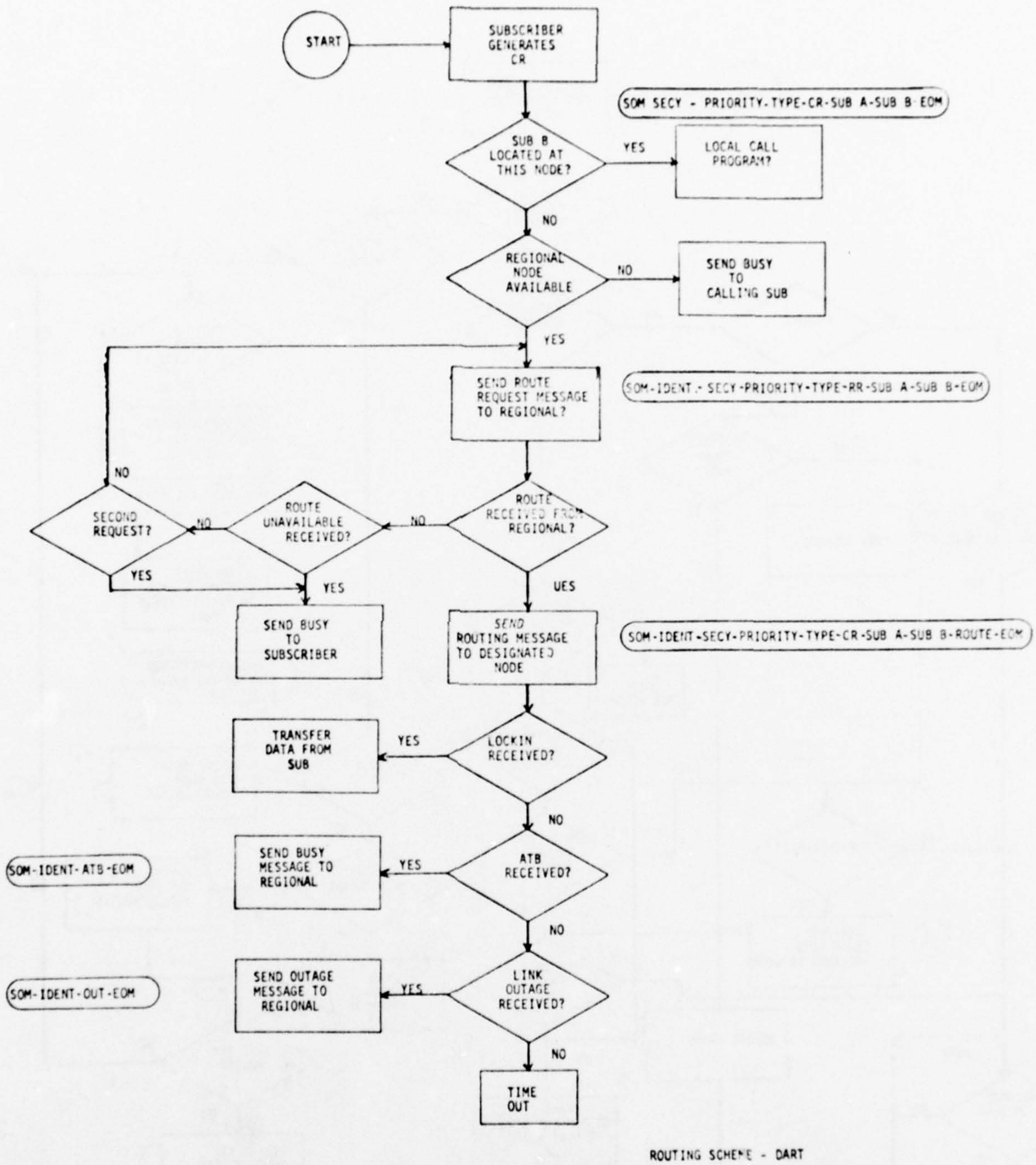

START
SUBSCRIBER GENERATES CR
SOM SECY - PRIORITY-TYPE-CR-SUB A-SUB B-EOM
SUB B LOCATED AT THIS NODE?
YES
LOCAL CALL PROGRAM?
NO
REGIONAL NODE AVAILABLE
NO
SEND BUSY TO CALLING SUB
YES
SEND ROUTE REQUEST MESSAGE TO REGIONAL?
SOM-IDENT - SECY-PRIORITY-TYPE-RR-SUB A-SUB B-EOM
NO
SECOND REQUEST?
NO
ROUTE UNAVAILABLE RECEIVED?
NO
ROUTE RECEIVED FROM REGIONAL?
YES
YES
SEND BUSY TO SUBSCRIBER
UES
SEND ROUTING MESSAGE TO DESIGNATED NODE
SOM-IDENT-SECY-PRIORITY-TYPE-CR-SUB A-SUB B-ROUTE-EOM
TRANSFER DATA FROM SUB
YES
LOCKIN RECEIVED?
NO
SOM-IDENT-ATB-EOM
SEND BUSY MESSAGE TO REGIONAL
YES
ATB RECEIVED?
NO
SOM-IDENT-OUT-EOM
SEND OUTAGE MESSAGE TO REGIONAL
YES
LINK OUTAGE RECEIVED?
NO
TIME OUT
ROUTING SCHEME - DART
NETWORK TYPE - HIERARCHICAL
MESSAGE TYPE - PNR OR VOICE
NODE TYPE - ORIGINATING TRIB

FIGURE 6-2

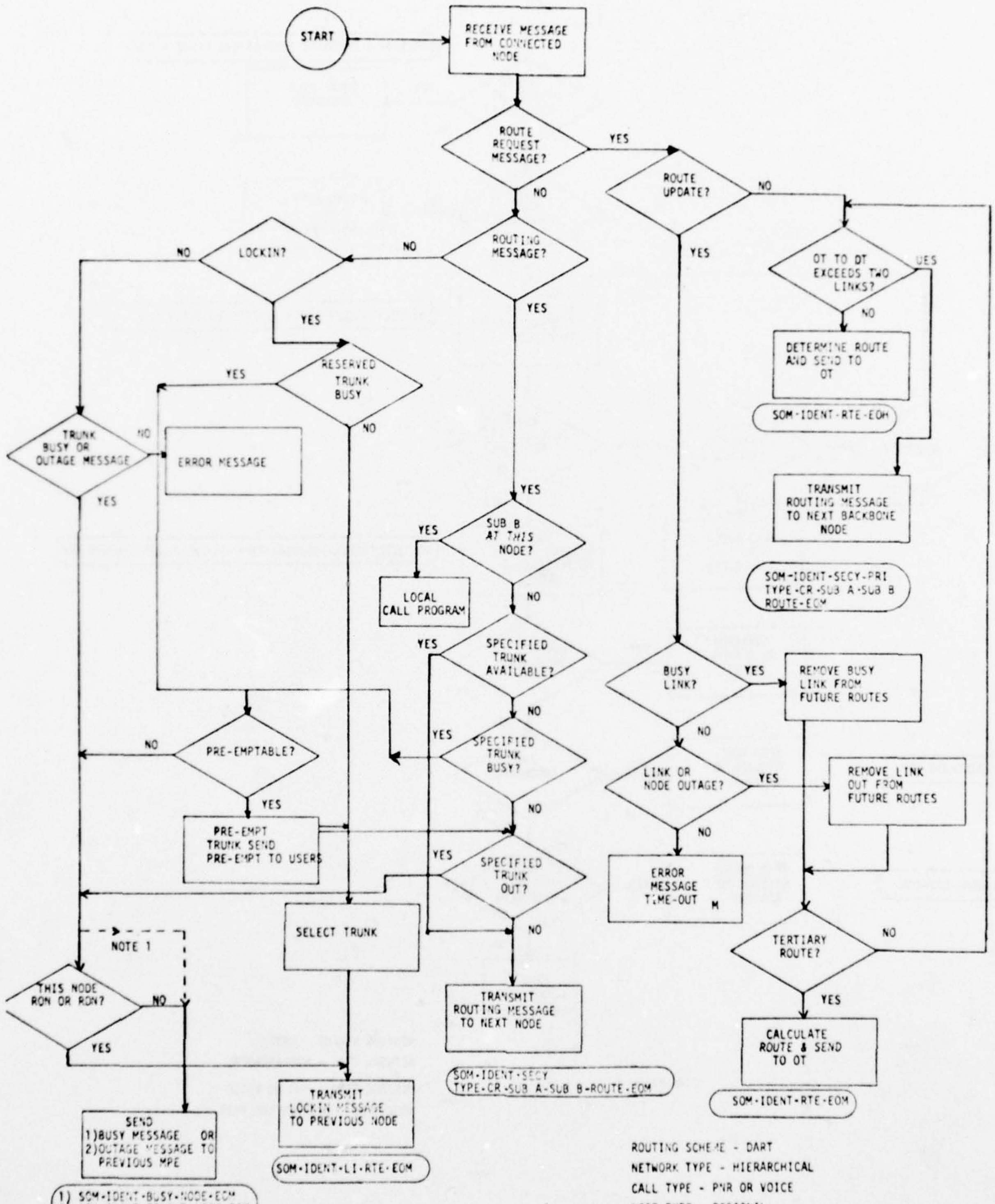


FIGURE 6-3

NOTE: RON/RDN DECISION NOT REQUIRING ON VOICE CALLS

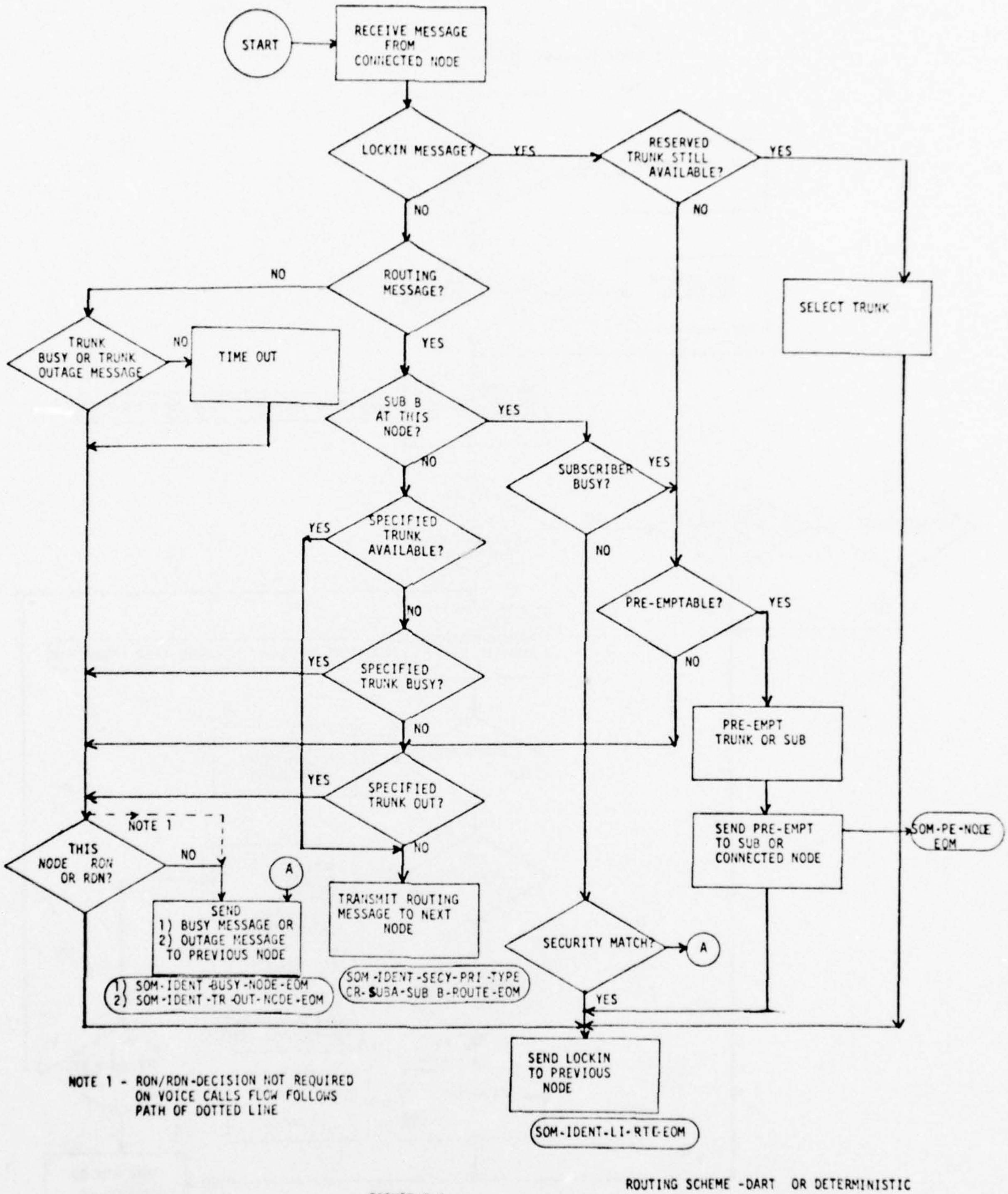


FIGURE 6-4

ROUTING SCHEME - DART OR DETERMINISTIC
NETWORK TYPE - NON-HIERARCHICAL
MESSAGE TYPE - PNR AND/OR HIERARCHICAL VOICE
NODE TYPE - INTERMEDIATE OR TERMINATING

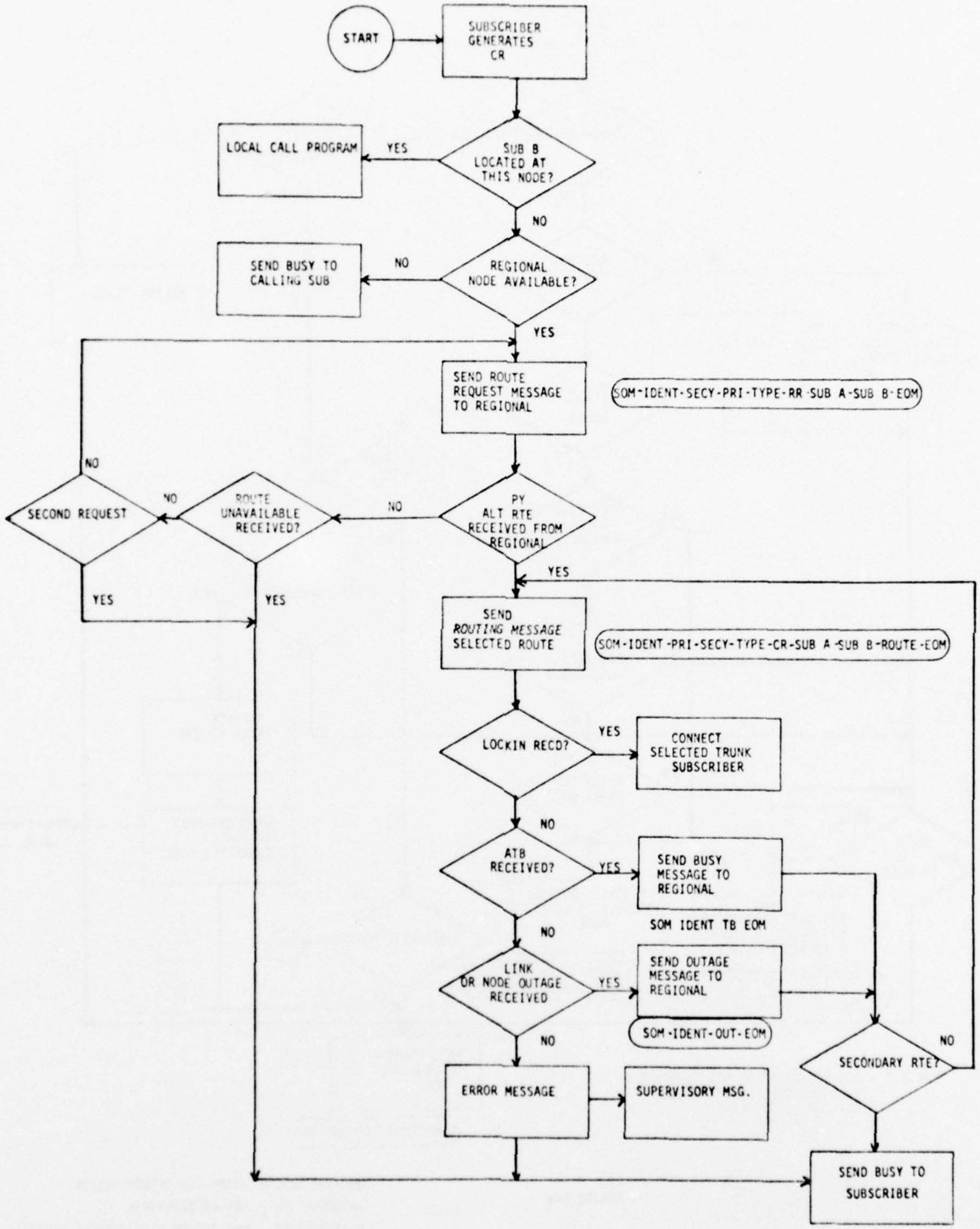
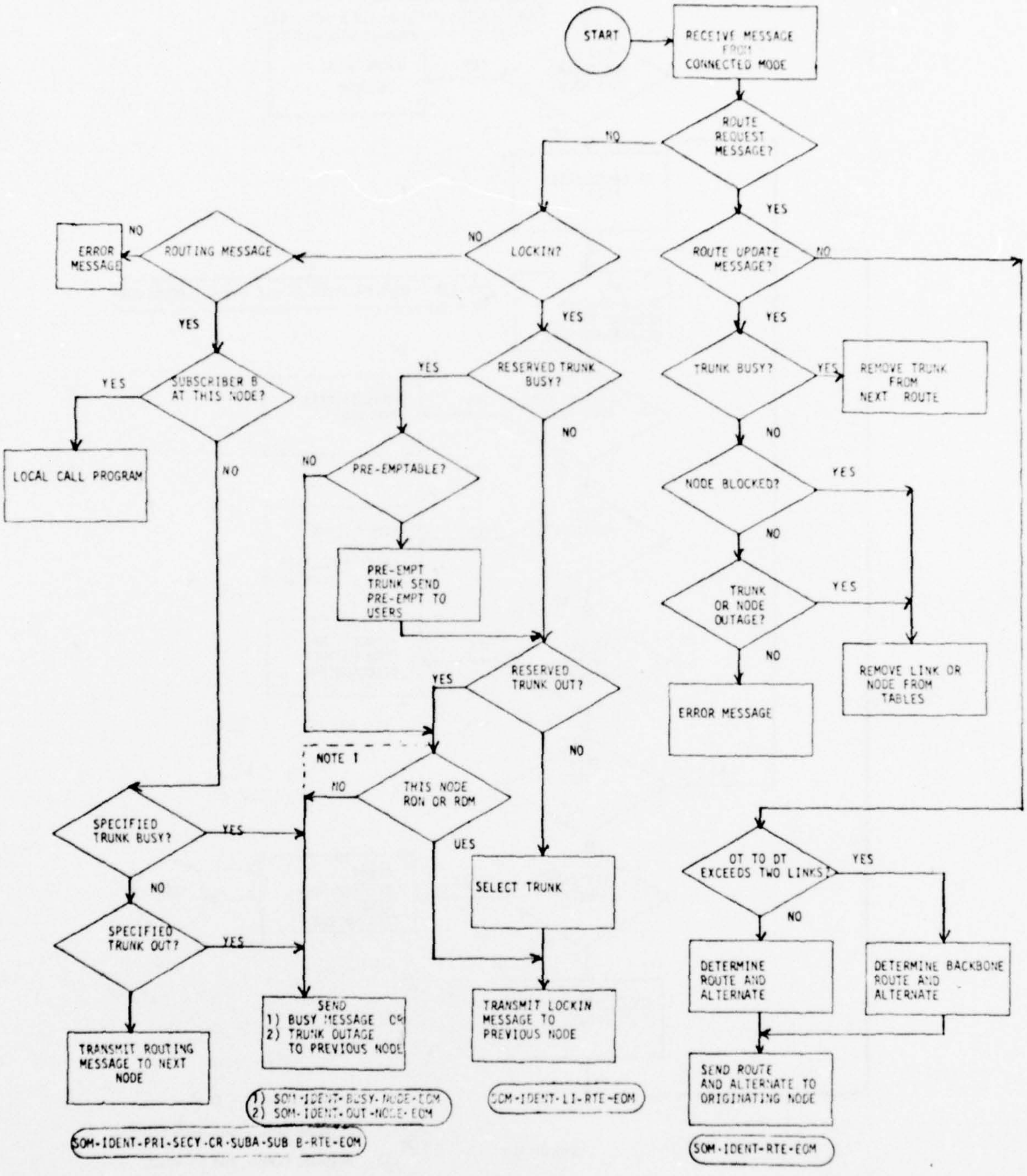


FIGURE 6-5

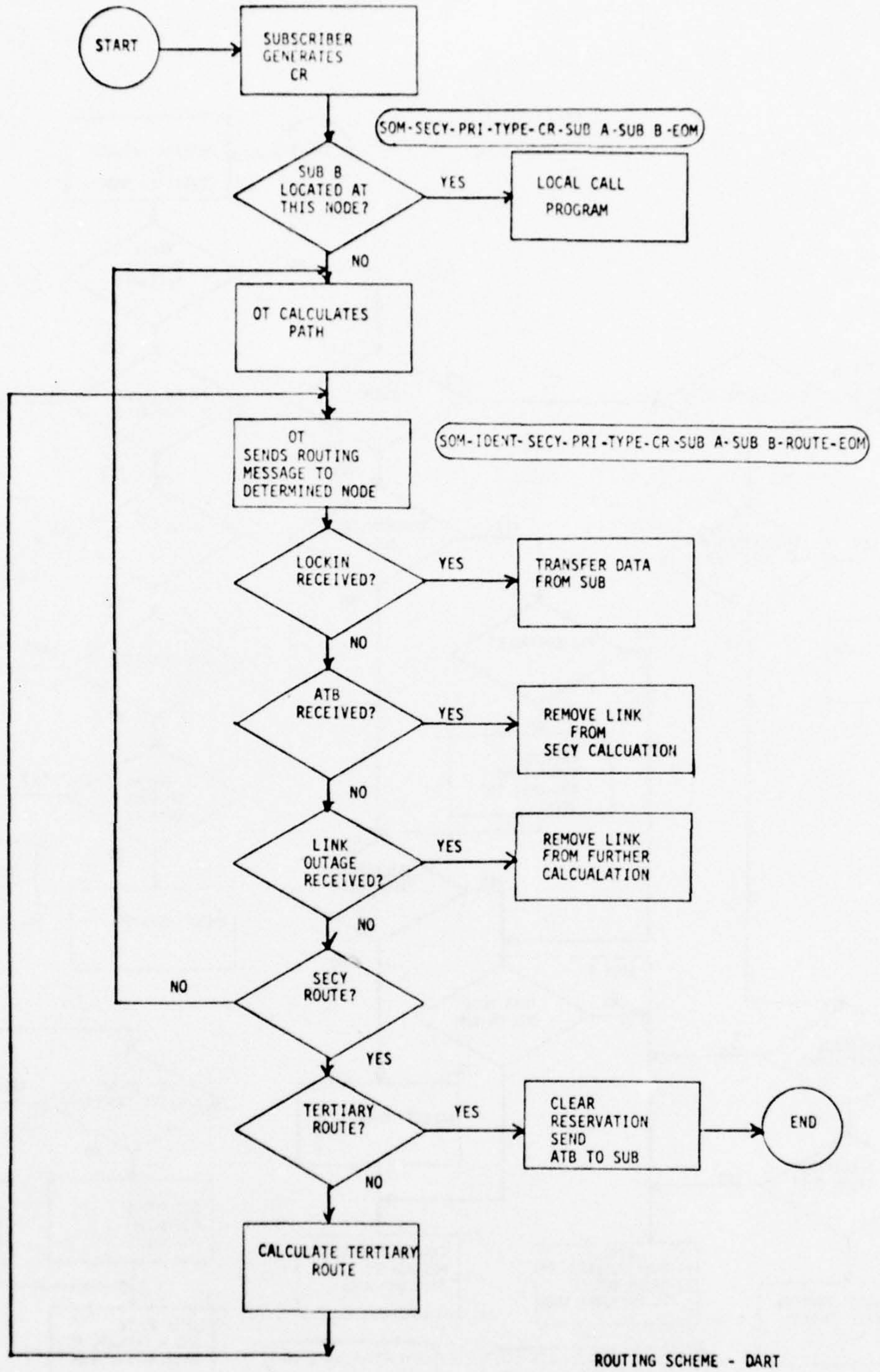
ROUTING SCHEME - DETERMINISTIC
NETWORK TYPE - HIERARCHICAL
MESSAGE TYPE - PNR OR VOICE
NODE TYPE - ORIGINATING TRIBUTARY



ROUTING SCHEME - DETERMINISTIC
NETWORK TYPE - NIERARCHICAL
CALL TYPE - PKR OR VOICE
NODE TYPE - REGIONAL

NOTE: RON/RDN DECISION NOT REQUIRED ON VOICE CALLS.

FIGURE 6-6



ROUTING SCHEME - DART
NETWORK TYPE - NON-HIERARCHICAL
MESSAGE TYPE - PNR OR VOICE
NODE TYPE - ORIGINATING TRIBUTARY

FIGURE 6-7

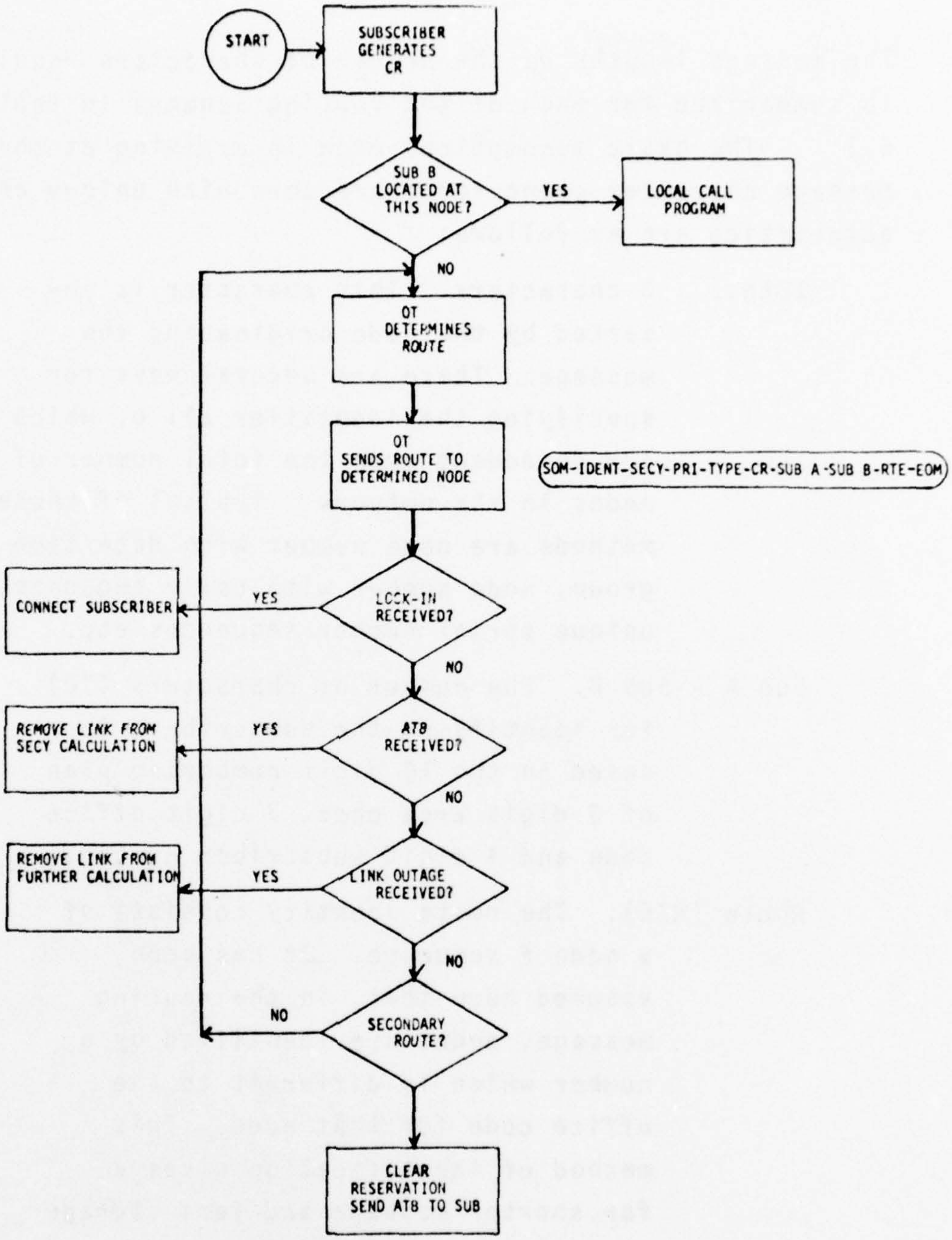


FIGURE 6-8

ROUTING SCHEME - DETERMINISTIC
NETWORK TYPE - NON-HIERARCHICAL
MESSAGE TYPE - PNR OR VOICE
NODE TYPE - ORIGINATING TRIBUTARY

the flow charts.

The message lengths by the number of characters required is summarized for each of the routing schemes in Table 6.1. The basic assumptions made in arriving at the message character count for characters with unique characteristics are as follows:

IDENT. 3 characters. This character is inserted by the node originating the message. There are several ways for specifying the identifier all of which are dependent upon the total number of nodes in the network. Typical of these methods are node number with date/time group, node number with daily sequence, unique serial number sequences etc.

Sub A - Sub B. The number of characters (10) for identifying the subscribers is based on the 10 digit numbering plan of 3 digit area code, 3 digit office code and 4 digit subscriber number.

Route (RTE). The route identity consists of a node # sequence. It has been assumed here that, in the routing message, nodes are identified by a number which is different to the office code for that node. This method of identification gives a far shorter message and less storage than office code identification.

The tributary to regional message in both DART and DETERMINISTIC shows six characters which are composed of 3 for

HIERARCHICAL — DART

	TRIB TO REGIONAL - RTE RQST.	TRIB TO REGIONAL - RTE & ALT.	TRIB TO REGIONAL - RTE UPDATE	TRIB TO INTERMEDIATE NODE	DESTN NODE TO TRIB (SUB BUSY)	INTERMEDIATE NODE - TRUNK BUSY	INTERMEDIATE NODE - TRUNK OUT	LOCKIN	REGIONAL TO TRIB - TERTIARY
SOM	1	1	1	1	1	1	1	1	1
IDENT	3	3	3	3	3	3	3	3	3
SECY	1	-	-	1	-	-	-	-	1
PRI	1	-	-	1	-	-	-	-	1
TYPE	1	-	1	1	1	1	1	1	1
SUB A	10	-	-	10	-	-	-	-	10
SUB B	10	-	-	10	-	-	-	-	10
RTE	-	6	-	3	-	-	-	-	-
LI	-	-	-	-	-	-	-	1	-
RR	1	-	-	-	-	-	-	-	-
ARR	-	-	-	-	-	-	-	-	1
BUSY	-	-	1*	-	-	2	-	-	-
OUT	-	-	1*	-	-	-	2	-	-
CR	1	1	-	1	-	-	-	-	-
EOM	1	1	1	1	1	1	1	1	1
TOTAL	30	12	7	32	6	8	8	7	29

HIERARCHICAL — DETERMINISTIC

	TRIB TO REGIONAL - RTE RQST	REGIONAL TO TRIB - RTE & ALT.	TRIB TO REGIONAL - RTE UPDATE	TRIB TO INTERMEDIATE NODE	DESTN NODE TO TRIB SUB BUSY	INTERMEDIATE NODE - TRUNK BUSY	INTERMEDIATE NODE - TRUNK OUT	LOCKIN
SOM	1	1	1	1	1	1	1	1
IDENT	3	3	3	3	3	3	3	3
SECY	1	-	-	1	-	-	-	-
PRI	1	-	-	1	-	-	-	-
TYPE	1	1	1	1	1	1	1	1
SUB A	10	-	-	10	-	-	-	-
SUB B	10	-	-	10	-	-	-	-
RTE	-	6	-	3	-	-	-	-
LI	-	-	-	-	-	-	-	1
RR	1	-	-	-	-	-	-	-
ARR	-	-	-	-	-	-	-	-
BUSY	-	-	1*	-	-	2	-	-
OUT	-	-	1*	-	-	-	2	-
CR	1	-	-	1	-	-	-	-
EOM	1	1	1	1	1	1	1	1
TOTAL	30	12	7	32	6	8	8	7

NON-HIERARCHICAL — DART / DETER.

	DART						DETER.				
	TRIB TO INTERMEDIATE	DESTN TO TRIB - SUB BUSY	INTERMEDIATE TO TRIB - TRUNK OUT	INTERMEDIATE TO TRIB - TRUNK BUSY	LOCKIN		TRIB TO INTERMEDIATE	DESTN TO TRIB - SUB BUSY	INTERMEDIATE TO TRIB - TRUNK OUT	INTERMEDIATE TO TRIB - TRUNK BUSY	LOCKIN
SOM	1	1	1	1	1		1	1	1	1	1
IDENT	3	3	3	3	3		3	3	3	3	3
SECY	1	-	-	-	-		1	-	-	-	-
PRI	1	-	-	-	-		1	-	-	-	-
TYPE	1	1	1	1	1		1	1	1	1	1
SUB A	10	-	-	-	-		10	-	-	-	-
SUB B	10	-	-	-	-		10	-	-	-	-
RTE	3	-	-	-	-		3	-	-	-	-
LI	-	-	-	-	1		-	-	-	-	1
RR	-	-	-	-	-		-	-	-	-	-
ARR	-	-	-	-	-		-	-	-	-	-
BUSY	-	-	-	2	-		-	-	-	2	-
OUT	-	-	2	-	-		-	-	2	-	-
CR	1	-	-	-	-		1	-	-	-	-
EOM	1	1	1	1	1		1	1	1	1	1
TOTAL	32	6	8	8	7		32	6	8	8	7

* ONE OF THESE TWO CHARACTERS USED IN THIS MESSAGE.

TABLE 6-1 MESSAGE CONTENT

the primary and 3 for the alternate. This assumes that a maximum of 3 nodes are traversed by a given message. In the actual routing message only 3 characters are required.

BUSY and OUT. Two characters have been assumed in these positions, one for identifying the reporting node and one for the trunk group out or busy at that node.

6.1.6 NETWORK CONTROL

As is readily apparent from Table 6-1, the difference between the number of message types between hierarchical and non-hierarchical is largely due to the additional messages required between tributary and regional nodes on the hierarchical network. The regional nodes at all times contain the information or the latest state of the network. This information is updated dynamically from trunk outage and trunk busy messages received in reply to routing messages. In the non-hierarchical network, all nodes have this information. In either case, the update of the network information as a dynamic basis takes place only when a routing message from a given point fails.

Thus, if a routing message does not transverse the point of failure, a given node may not be informed of the failure until such time as it generates a message across this point.

This form of graceful degradation can be seen as a definite advantage although under certain traffic conditions and without rearrangements to routing tables, serious network blockages might ensue.

Dynamic updating of network control information as an integral function of the routing scheme should be augmented by a quasi-dynamic scheme whereby network information can be accumulated at a central point and disseminated to nodes as required over a dedicated channel.

This is particularly true in a tactical network where changes to network configuration can be so drastic as to completely alter the inter-relationship of all nodes, thus requiring that routing tables at each node be changed, a function which is beyond the capability of the routing schemes.

6.2 MEMORY REQUIREMENTS

6.2.1 INTRODUCTION

This section evaluates the impact of candidate signaling/supervision and routing schemes on program and memory size for different capacity circuit switch modules. Both deterministic (DET) and deterministic/adaptive (DART) routing schemes are considered for circuit switch sizes ranging from 300 to 2400 lines in modular increments of 300 lines. Flowcharts representing the ICMS controller are used as a baseline for the development of estimates of single thread call processing times in both non-hierarchical and hierarchical network structures.

6.2.2 NETWORK CONSIDERATIONS

The analysis presented below is based upon a generalized network topology which is assumed to be composed of N nodes and some associated internodal connectivity. For purely illustrative purposes in determining quantitative memory storage requirements, assume that the network under consideration has seventeen nodes, that is, N = 17, as in

the simulation model. Detailed specification of the network connectivity is relatively unimportant for the purposes of this discussion; however, assume that the maximum number of nodes included in any network path between a calling and a called subscriber is limited to seven.

A valid deterministic routing algorithm can be defined as a table look-up of information which specifies the <u>entire</u> network path between any two nodes in terms of an ordered sequence of up to seven intermediate nodes. This path is obtained from a static routing table at the originating node in a non-hierarchical network or at a regional node in a hierarchical network. In either case, this routing table is presumed to contain primary and secondary[(1)] paths between every pair of nodes in the network subject to the seven node maximum limit mentioned above. These paths can be generated offline by a calculating path algorithm according to any desired path optimization criteria.

Operation of the deterministic routing algorithm is relatively simple. In a non-hierarchical network, the path information is obtained at the originating node; in a hierarchical network, the path must be obtained from a connected regional node. (In the case of a tributary requesting path information from a regional node in a hierarchical network, it is probably advantageous for the

---

(1) Obviously, for a specific application, the number of stored routes might be greater than two.

path response to include both primary and secondary path information.) In either type of network, a connection request is generated and sent out over the primary path by the originating node. If this attempt proves unsuccessful, the secondary path is obtained, a connection request is generated and sent out over the secondary path by the originating node. If this alternate path fails, the call attempt is abandoned.

An obvious extension of the deterministic routing algorithm results in the definition of an interesting hybrid: a deterministic/adaptive routing algorithm. DART involves a table look-up of information which specifies the <u>entire</u> network path, just as in the deterministic routing algorithm explained above. Both primary and secondary path information is obtained in this manner at the originating node in a non-hierarchical network, or at a regional node in a hierarchical network. In either case, the routing table utilized is identical to the table employed in the deterministic algorithm. The paths contained in this routing table can be generated offline by a path calculator algorithm according to any desired path optimization criteria.

The adaptive part of DART consists of the on-line calculation of a tertiary path between any two nodes based on the information deduced from the failures of the primary and secondary routes; this represents a complete departure from the deterministic routing algorithm.

Nonetheless, operation of DART is equivalent to the selection of primary and secondary paths by the previously defined deterministic algorithm with the dynamic calculation of a tertiary path based upon failure information

derived from two unsuccessful deterministic routing attempts (if required). If the tertiary route fails, the call is abandoned.

Within the context of these definitions, the deterministic routing algorithm is simply a subset of DART. It is easy to envision a situation in which the adaptive routing algorithm which characterizes DART is contained in an overlay on a mass storage device at a switching center[2]. This overlay could be read into core memory and executed to perform dynamic path calculation on an as-required basis. However, in order to assure that "apples are compared with apples", assume that all programs and tables are resident in core memory for the purpose of estimating program and memory sizes.

6.2.3 MEMORY SIZE CONSIDERATIONS

Requirements for core memory at the nodes of the generalized network can be divided into two distinct categories: program (instruction) storage and table storage. The characteristics of these two categories are very different. Program size depends primarily on the functions provided while table size depends primarily on the number of terminations. Nonetheless, some interdependency between program and tables does exist.

---

(2) Another implementation might be a dedicated processing function assigned to calculating route alternatives, if the load at a center warrents it.

For the purposes of illustrating memory requirements, consider a regional node in a hierarchical network. This choice permits the representation of a "typical" node in a generalized network as an upper bound for estimating program and memory sizes for different capacity circuit switches. The regional node is typical in the sense that every node in a non-hierarchical network is a regional node, and the size of tributary nodes in hierarchical networks is bounded, above, by the regional node.

Program size for regional nodes was estimated on the basis of work done on the ICMS controller, with appropriate modifications made for the deterministic and deterministic/adaptive routing algorithms under consideration. The results of this process are shown in Figure 6-9. The program size varies with the complexity of the routing scheme implemented, but remains essentially fixed for different capacity circuit switches for a particular routing algorithm.

Memory requirements for table storage are primarily dependent upon the number of circuit switch terminations and, to a lesser degree, upon the selected routing algorithm. Detailed estimates of the table storage required for different capacity circuit switches are given for regional nodes with deterministic routing algorithms in Figures 6-10 through 6-17 and with deterministic/adaptive routing algorithms in Figures 6-18 through 6-25. Total memory requirements (program plus tables) for each modular increment of 300 lines is plotted for DET and DART schemes in Figure 6-26.

Figure 6-9

PROGRAM SIZE FOR A REGIONAL NODE

	DET	DART
Operating System	13,000	13,500
Communications Channel Service	6,500	6,500
Circuit Switch Subsystem	12,500	14,000
Routing Table Look-Up	1,000	1,000
Adaptive Matrix Reconfiguration	-	3,000
Path Calculator	-	4,400
	33,000 bytes	42,500 bytes

Deterministic Routing, 300 Lines

Figure 6-10

TABLE SIZE

TERMINATION TABLE

a. 270 lines @ 16 bytes/line		4320
b. 30 trunks @ 16 bytes/trunk		480
RECEIVER/SENDER TABLE	7 @ 16 bytes/RS	112
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	-
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	-
INFORMATION MATRIX	N entries @ 12 bytes/entry	-
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3808
TRUNK TABLE	30 trunks @ 8 bytes/trunk	240
OOB CHANNEL TABLE	3 OOB channels @ 32 bytes/channel	96
TRUNK GROUP TABLE	3 groups @ 4 bytes/group	12
HUNT GROUP TABLE	3 hunt groups @ 20 bytes/group	60
STATUS & SCAN TABLES	1 units @ 136 bytes/unit	136
QUEUES	1 modules @ 912 bytes/module	912
CALL ATTENDANT TABLE	1 attendants @ 32 bytes/attendant	32
CONSTANTS & WORK AREA		1000
	TOTAL	13,608
		46,608

Deterministic Routing, 600 Lines

Figure 6-11

TABLE SIZE

TERMINATION TABLE

a. 540 lines @ 16 bytes/line		8640
b. 60 trunks @ 16 bytes/trunk		960
RECEIVER/SENDER TABLE	12 @ 16 bytes/RS	192
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	-
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	-
INFORMATION MATRIX	N entries @ 12 bytes/entry	-
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3808
TRUNK TABLE	60 trunks @ 8 bytes/trunk	480
OOB CHANNEL TABLE	6 OOB channels @ 32 bytes/channel	192
TRUNK GROUP TABLE	6 groups @ 4 bytes/group	24
HUNT GROUP TABLE	6 hunt groups @ 20 bytes/group	120
STATUS & SCAN TABLES	2 units @ 136 bytes/unit	272
QUEUES	2 modules @ 912 bytes/module	1824
CALL ATTENDANT TABLE	1 attendants @ 32 bytes/attendant	32
CONSTANTS & WORK AREA		1000
	TOTAL	19,944
		52,944

Deterministic Routing, 900 Lines

Figure 6-12

TABLE SIZE		
TERMINATION TABLE		
a. 810 lines @ 16 bytes/line		12,960
b. 90 trunks @ 16 bytes/trunk		1,440
RECEIVER/SENDER TABLE	17 @ 16 bytes/RS	272
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	-
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	-
INFORMATION MATRIX	N entries @ 12 bytes/entry	-
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	90 trunks @ 8 bytes/trunk	720
OOB CHANNEL TABLE	9 OOB channels @ 32 bytes/channel	288
TRUNK GROUP TABLE	9 groups @ 4 bytes/group	36
HUNT GROUP TABLE	9 hunt groups @ 20 bytes/group	180
STATUS & SCAN TABLES	3 units @ 136 bytes/unit	408
QUEUES	3 modules @ 912 bytes/module	2,736
CALL ATTENDANT TABLE	1 attendants @ 32 bytes/attendant	32
CONSTANTS & WORK AREA		1,000
	TOTAL	26,280
		59,280

Deterministic Routing, 1200 Lines

Figure 6-13

TABLE SIZE		
TERMINATION TABLE		
a. 1080 lines @ 16 bytes/line		17,280
b. 120 trunks @ 16 bytes/trunk		1,920
RECEIVER/SENDER TABLE	22 @ 16 bytes/RS	352
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	-
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	-
INFORMATION MATRIX	N entries @ 12 bytes/entry	-
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	120 trunks @ 8 bytes/trunk	960
OOB CHANNEL TABLE	12 OOB channels @ 32 bytes/channel	384
TRUNK GROUP TABLE	12 groups @ 4 bytes/group	48
HUNT GROUP TABLE	12 hunt groups @ 20 bytes/group	240
STATUS & SCAN TABLES	4 units @ 136 bytes/unit	544
QUEUES	4 modules @ 912 bytes/module	3,648
CALL ATTENDANT TABLE	1 attendants @ 32 bytes/attendant	32
CONSTANTS & WORK AREA		1,000
	TOTAL	32,616
		65,616

Deterministic Routing, 1500 Lines

Figure 6-14

TABLE SIZE		
TERMINATION TABLE		
a. 1350 lines @ 16 bytes/line		21,600
b. 150 trunks @ 16 bytes/trunk		2,400
RECEIVER/SENDER TABLE	27 @ 16 bytes/RS	432
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	-
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	-
INFORMATION MATRIX	N entries @ 12 bytes/entry	-
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	150 trunks @ 8 bytes/trunk	1,200
OOB CHANNEL TABLE	15 OOB channels @ 32 bytes/channel	480
TRUNK GROUP TABLE	15 groups @ 4 bytes/group	60
HUNT GROUP TABLE	15 hunt groups @ 20 bytes/group	300
STATUS & SCAN TABLES	5 units @ 136 bytes/unit	680
QUEUES	5 modules @ 912 bytes/module	4,560
CALL ATTENDANT TABLE	2 attendants @ 32 bytes/attendant	64
CONSTANTS & WORK AREA		1,000
	TOTAL	38,984
		71,984

Deterministic Routing, 1800 Lines

Figure 6-15

TABLE SIZE

TERMINATION TABLE

a. 1620 lines @ 16 bytes/line		25,920
b. 180 trunks @ 16 bytes/trunk		2,880
RECEIVER/SENDER TABLE	31 @ 16 bytes/RS	496
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	-
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	-
INFORMATION MATRIX	N entries @ 12 bytes/entry	-
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	180 trunks @ 8 bytes/trunk	1,440
OOB CHANNEL TABLE	18 OOB channels @ 32 bytes/channel	576
TRUNK GROUP TABLE	18 groups @ 4 bytes/group	72
HUNT GROUP TABLE	18 hunt groups @ 20 bytes/group	360
STATUS & SCAN TABLES	6 units @ 136 bytes/unit	816
QUEUES	6 modules @ 912 bytes/module	5,472
CALL ATTENDANT TABLE	2 attendants @ 32 bytes/attendant	64
CONSTANTS & WORK AREA		1,000
	TOTAL	45,304
		78,304

Deterministic Routing, 2100 Lines

Figure 6-16

TABLE SIZE		
TERMINATION TABLE		
	a. 1890 lines @ 16 bytes/line	30,240
	b. 210 trunks @ 16 bytes/trunk	3,360
RECEIVER/SENDER TABLE	36 @ 16 bytes/RS	576
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	-
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	-
INFORMATION MATRIX	N entries @ 12 bytes/entry	-
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,707
TRUNK TABLE	210 trunks @ 8 bytes/trunk	1,680
OOB CHANNEL TABLE	21 OOB channels @ 32 bytes/channel	672
TRUNK GROUP TABLE	21 groups @ 4 bytes/group	84
HUNT GROUP TABLE	21 hunt groups @ 20 bytes/group	420
STATUS & SCAN TABLES	7 units @ 136 bytes/unit	952
QUEUES	7 modules @ 912 bytes/module	6,384
CALL ATTENDANT TABLE	2 attendants @ 32 bytes/attendant	64
CONSTANTS & WORK AREA		1,000
	TOTAL	51,640
		84,640

Deterministic Routing, 2400 Lines

Figure 6-17

TABLE SIZE		
TERMINATION TABLE		
a. 2160 lines @ 16 bytes/line		34,560
b. 240 trunks @ 16 bytes/trunk		3,840
RECEIVER/SENDER TABLE	40 @ 16 bytes/RS	640
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	-
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	-
INFORMATION MATRIX	N entries @ 12 bytes/entry	-
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	240 trunks @ 8 bytes/trunk	1,920
OOB CHANNEL TABLE	24 OOB channels @ 32 bytes/channel	768
TRUNK GROUP TABLE	24 groups @ 4 bytes/group	96
HUNT GROUP TABLE	24 hunt groups @ 20 bytes/group	480
STATUS & SCAN TABLES	8 units @ 136 bytes/unit	1,088
QUEUES	8 modules @ 912 bytes/module	7,296
CAL'. ATTENDANT TABLE	2 attendants @ 32 bytes/attendant	64
CONSTANTS & WORK AREA		1,000
	TOTAL	57,960
		90,960

DART, 300 Lines

Figure 6-18

TABLE SIZE		
TERMINATION TABLE		
a. 270 lines @ 16 bytes/line		4,320
b. 30 trunks @ 16 bytes/trunk		480
RECEIVER/SENDER TABLE	7 @ 16 bytes/RS	112
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	578
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	578
INFORMATION MATRIX	N entries @ 12 bytes/entry	204
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	30 trunks @ 8 bytes/trunk	240
OOB CHANNEL TABLE	3 OOB channels @ 32 bytes/channel	96
TRUNK GROUP TABLE	3 groups @ 4 bytes/group	12
HUNT GROUP TABLE	3 hunt groups @ 20 bytes/group	60
STATUS & SCAN TABLES	1 units @ 136 bytes/unit	136
QUEUES	1 modules @ 912 bytes/module	912
CALL ATTENDANT TABLE	1 attendants @ 32 bytes/attendant	32
CONSTANTS & WORK AREA		1,000
	TOTAL	14,968
		57,368

DART, 600 Lines

Figure 6-19

TABLE SIZE		
TERMINATION TABLE		
a. 540 lines @ 16 bytes/line		8,640
b. 60 trunks @ 16 bytes/trunk		960
RECEIVER/SENDER TABLE	12 @ 16 bytes/RS	192
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	578
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	578
INFORMATION MATRIX	N entries @ 12 bytes/entry	204
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	1,808
TRUNK TABLE	60 trunks @ 8 bytes/trunk	480
OOB CHANNEL TABLE	6 OOB channels @ 32 bytes/channel	192
TRUNK GROUP TABLE	6 groups @ 4 bytes/group	24
HUNT GROUP TABLE	6 hunt groups @ 20 bytes/group	120
STATUS & SCAN TABLES	2 units @ 136 bytes/unit	272
QUEUES	2 modules @ 912 bytes/module	1,824
CALL ATTENDANT TABLE	1 attendants @ 32 bytes/attendant	32
CONSTANTS & WORK AREA		1,000
	TOTAL	21,304
		63,704

DART, 900 Lines

Figure 6-20

TABLE SIZE		
TERMINATION TABLE		
	a. 810 lines @ 16 bytes/line	12,960
	b. 90 trunks @ 16 bytes/trunk	1,440
RECEIVER/SENDER TABLE	17 @ 16 bytes/RS	272
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	578
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	578
INFORMATION MATRIX	N entries @ 12 bytes/entry	204
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	90 trunks @ 8 bytes/trunk	720
OOB CHANNEL TABLE	9 OOB channels @ 32 bytes/channel	288
TRUNK GROUP TABLE	9 groups @ 4 bytes/group	36
HUNT GROUP TABLE	9 hunt groups @ 20 bytes/group	180
STATUS & SCAN TABLES	3 units @ 136 bytes/unit	408
QUEUES	3 modules @ 912 bytes/module	2,736
CALL ATTENDANT TABLE	1 attendants @ 32 bytes/attendant	32
CONSTANTS & WORK AREA		1,000
	TOTAL	27,640
		70,040

DART, 1200 Lines

Figure 6-21

TABLE SIZE		
TERMINATION TABLE		
a. 1080 lines @ 16 bytes/line		17,280
b. 120 trunks @ 16 bytes/trunk		1,920
RECEIVER/SENDER TABLE	22 @ 16 bytes/RS	352
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	578
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	578
INFORMATION MATRIX	N entries @ 12 bytes/entry	204
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	120 trunks @ 8 bytes/trunk	960
OOB CHANNEL TABLE	12 OOB channels @ 32 bytes/channel	384
TRUNK GROUP TABLE	12 groups @ 4 bytes/group	48
HUNT GROUP TABLE	12 hunt groups @ 20 bytes/group	240
STATUS & SCAN TABLES	4 units @ 136 bytes/unit	544
QUEUES	4 modules @ 912 bytes/module	3,648
CALL ATTENDANT TABLE	1 attendants @ 32 bytes/attendant	32
CONSTANTS & WORK AREA		1,000
	TOTAL	33,976
		76,376

DART, 1500 Lines

Figure 6-22

TABLE SIZE

TERMINATION TABLE

a. 1350 lines @ 16 bytes/line		21,600
b. 150 trunks @ 16 bytes/trunk		2,400
RECEIVER/SENDER TABLE	27 @ 16 bytes/RS	432
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	578
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	578
INFORMATION MATRIX	N entries @ 12 bytes/entry	204
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	150 trunks @ 8 bytes/trunk	1,200
OOB CHANNEL TABLE	15 OOB channels @ 32 bytes/channel	480
TRUNK GROUP TABLE	15 groups @ 4 bytes/group	60
HUNT GROUP TABLE	15 hunt groups @ 20 bytes/group	300
STATUS & SCAN TABLES	5 units @ 136 bytes/unit	680
QUEUES	5 modules @ 912 bytes/module	4,560
CALL ATTENDANT TABLE	2 attendants @ 32 bytes/attendant	64
CONSTANTS & WORK AREA		1,000
	TOTAL	40,344
		82,744

DART, 1800 Lines

Figure 6-23

TABLE SIZE		
TERMINATION TABLE		
a. 1620 lines @ 16 bytes/line		25,920
b. 180 trunks @ 16 bytes/trunk		2,880
RECEIVER/SENDER TABLE	31 @ 16 bytes/RS	496
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	578
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	578
INFORMATION MATRIX	N entries @ 12 bytes/entry	204
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	180 trunks @ 8 bytes/trunk	1,440
OOB CHANNEL TABLE	18 OOB channels @ 32 bytes/channel	576
TRUNK GROUP TABLE	18 groups @ 4 bytes/group	72
HUNT GROUP TABLE	18 hunt groups @ 20 bytes/group	360
STATUS & SCAN TABLES	6 units @ 136 bytes/unit	816
QUEUES	6 modules @ 912 bytes/module	5,472
CALL ATTENDANT TABLE	2 attendants @ 32 bytes/attendant	64
CONSTANTS & WORK AREA		1,000
	TOTAL	46,664
		89,064

DART, 2100 Lines

Figure 6-24

TABLE SIZE		
TERMINATION TABLE		
	a. 1890 lines @ 16 bytes/line	30,240
	b. 210 trunks @ 16 bytes/trunk	3,360
RECEIVER/SENDER TABLE	36 @ 16 bytes/RS	576
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	578
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	578
INFORMATION MATRIX	N entries @ 12 bytes/entry	204
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	210 trunks @ 8 bytes/trunk	1,680
OOB CHANNEL TABLE	21 OOB channels @ 32 bytes/channel	673
TRUNK GROUP TABLE	21 groups @ 4 bytes/group	84
HUNT GROUP TABLE	21 hunt groups @ 20 bytes/group	420
STATUS & SCAN TABLES	7 units @ 136 bytes/unit	952
QUEUES	7 modules @ 912 bytes/module	6,384
CALL ATTENDANT TABLE	2 attendants @ 32 bytes/attendant	64
CONSTANTS & WORK AREA		1,000
	TOTAL	53,000
		95,400

DART, 2400 Lines

Figure 6-25

TABLE SIZE		
TERMINATION TABLE		
a. 2160 lines @ 16 bytes/line		34,560
b. 240 trunks @ 16 bytes/trunk		3,840
RECEIVER/SENDER TABLE	40 @ 16 bytes/RS	640
REMOTE AREA CODE TABLE	200 @ 3 bytes/code	600
REMOTE EXCHANGE TABLE	600 @ 3 bytes/code	1,800
CONNECTIVITY MATRIX	NXN entries @ 2 bytes/entry	578
DIRECTORY MATRIX	NXN entries @ 2 bytes/entry	578
INFORMATION MATRIX	N entries @ 12 bytes/entry	204
STORED PATH ROUTING TABLE	2N (N-1) entries @ 7 bytes/entry	3,808
TRUNK TABLE	240 trunks @ 8 bytes/trunk	1,920
OOB CHANNEL TABLE	24 OOB channels @ 32 bytes/channel	768
TRUNK GROUP TABLE	24 groups @ 4 bytes/group	96
HUNT GROUP TABLE	24 hunt groups @ 20 bytes/group	480
STATUS & SCAN TABLES	8 units @ 136 bytes/unit	1,088
QUEUES	8 modules @ 912 bytes/module	7,296
CALL ATTENDANT TABLE	2 attendants @ 32 bytes/attendant	64
CONSTANTS & WORK AREA		1,000
	TOTAL	59,320
		101,720

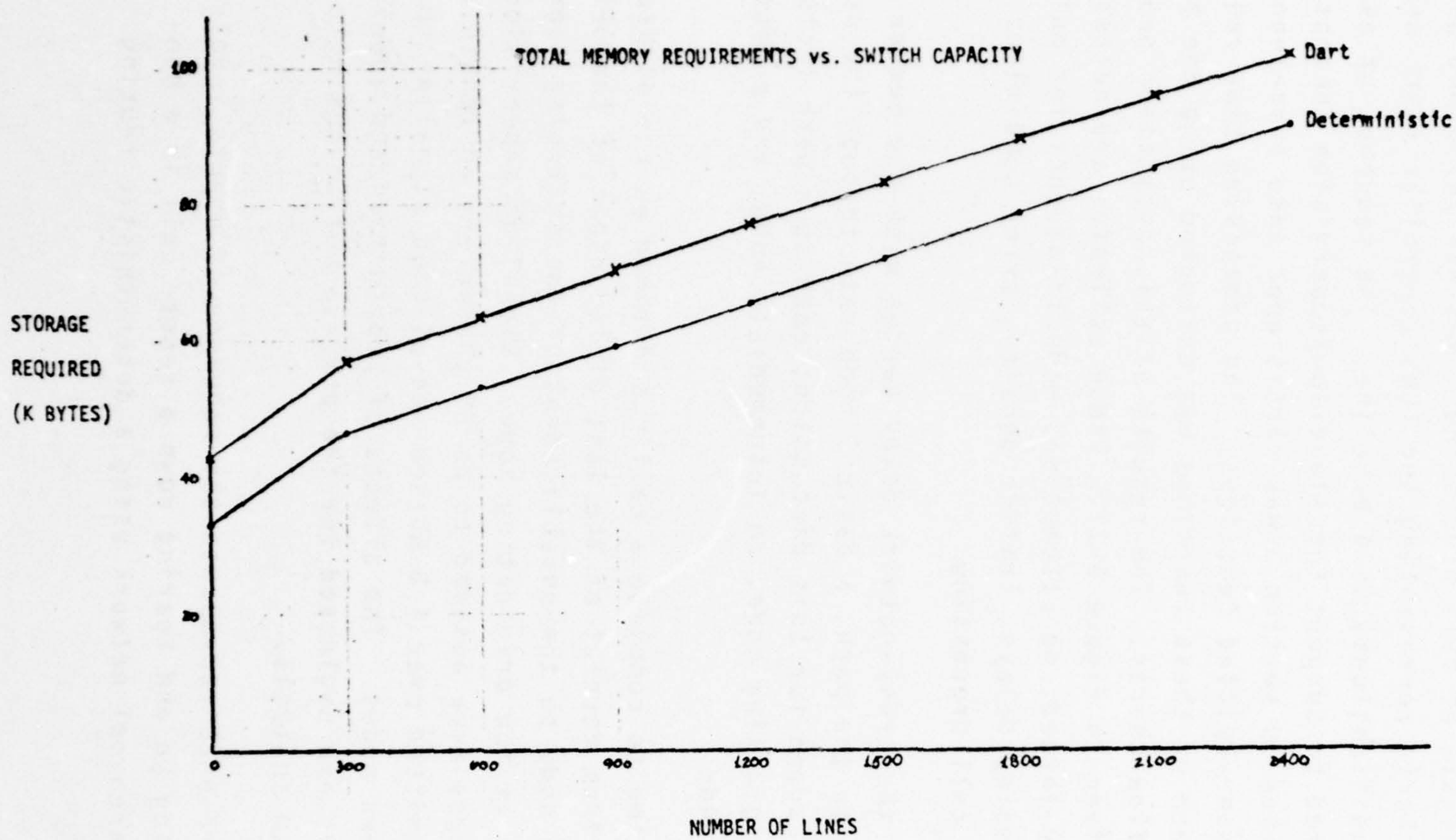

TOTAL MEMORY REQUIREMENTS vs. SWITCH CAPACITY
Dart
Deterministic
STORAGE
REQUIRED
(K BYTES)
100
80
60
40
20
0
300
600
900
1200
1500
1800
2100
2400
NUMBER OF LINES

Figure 6-26

6.2.4 CALL PROCESSING TIME CONSIDERATIONS

An analysis of call processing times was performed using flow charts representing the ICMS controller (with necessary modifications) as a baseline. The sequence of events required to support the signaling/supervision concepts described in section 3 was partitioned into seventeen processor-related functions. The processing time required for each of these functions was estimated using the baseline flow charts. The results of this estimation process are given in Figure 6-27. These estimates are necessarily single-thread; no attempt was made to account for multiprocessing delays, traffic density, error conditions, or local call processing.

Since the cross-network delay varies with the number of nodes in the path, a basic 3 node path through the network was assumed for this discussion; each such path included an originating node, an intermediate node, and a destination node.

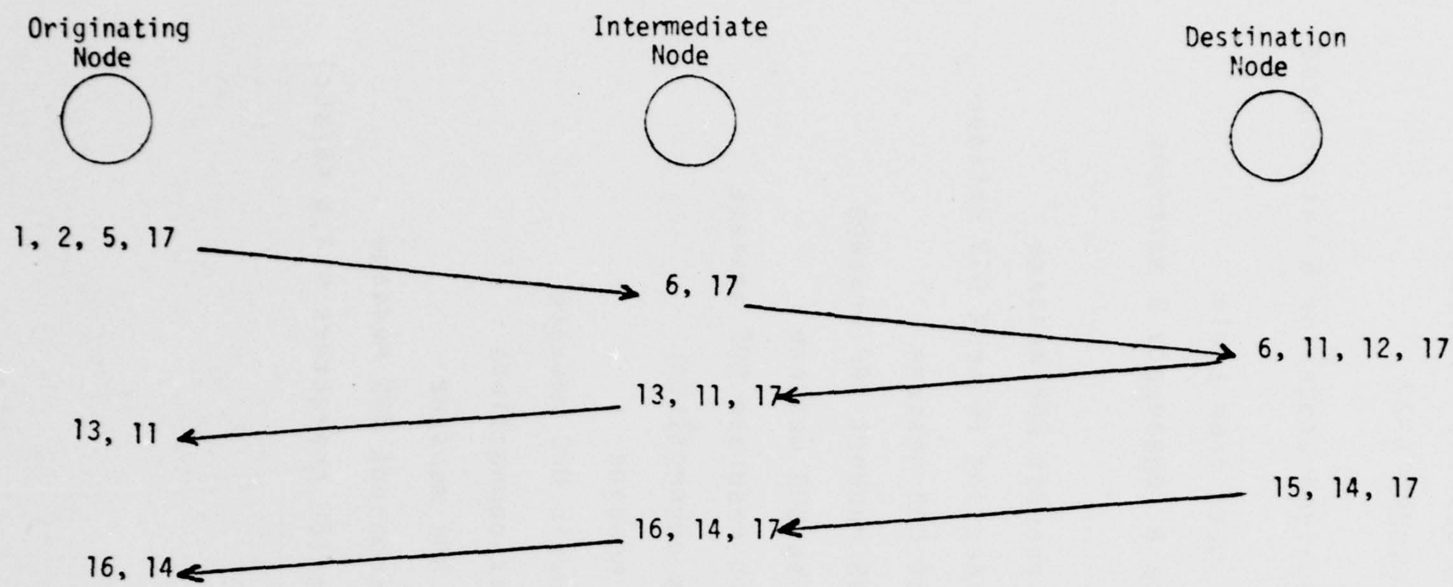
The time to complete a call was defined as the elapsed time from receipt of the last dialed digit at the originating node to the establishment of the switching connections at the originating node. Signaling/supervision messages were assumed to be 20 characters in length and transmitted over 4.8 KB/sec out-of-band signaling channels between nodes. The effects of propagation and queuing delays are neglected for the purposes of this single-thread analysis.

Figure 6-28 represents the sequence of events involved in setting up and tearing down a remote call in a non-hierarchical network using a deterministic routing scheme.

ESTIMATED PROCESSING TIMES FOR SELECTED CALL PROCESSING FUNCTIONS

FIGURE 6-27

1.	Last dialed digit received processor & interrupted (maximum)	20 msec
2.	Obtain deterministic path from table	1 msec
3.	Evaluate failure data & regenerate 2 matrices	314 msec
4.	Calculate new path	136 msec
5.	Generate connection request OOB message	2 msec
6.	Process received connection request OOB message	1 msec
7.	Generate path request OOB message	2 msec
8.	Process received path request OOB message	1 msec
9.	Generate path response OOB message	2 msec
10.	Process received path response OOB message	1 msec
11.	Make & test 2 matrix connections	5 msec
12.	Generate lockin OOB message	2 msec
13.	Process received lockin OOB message	1 msec
14.	Break & test 2 matrix connections	3 msec
15.	Generate disconnect OOB message	2 msec
16.	Process received disconnect OOB message	1 msec
17.	Transmit OOB message (20 characters @ 4.8 KB/sec)	33 msec



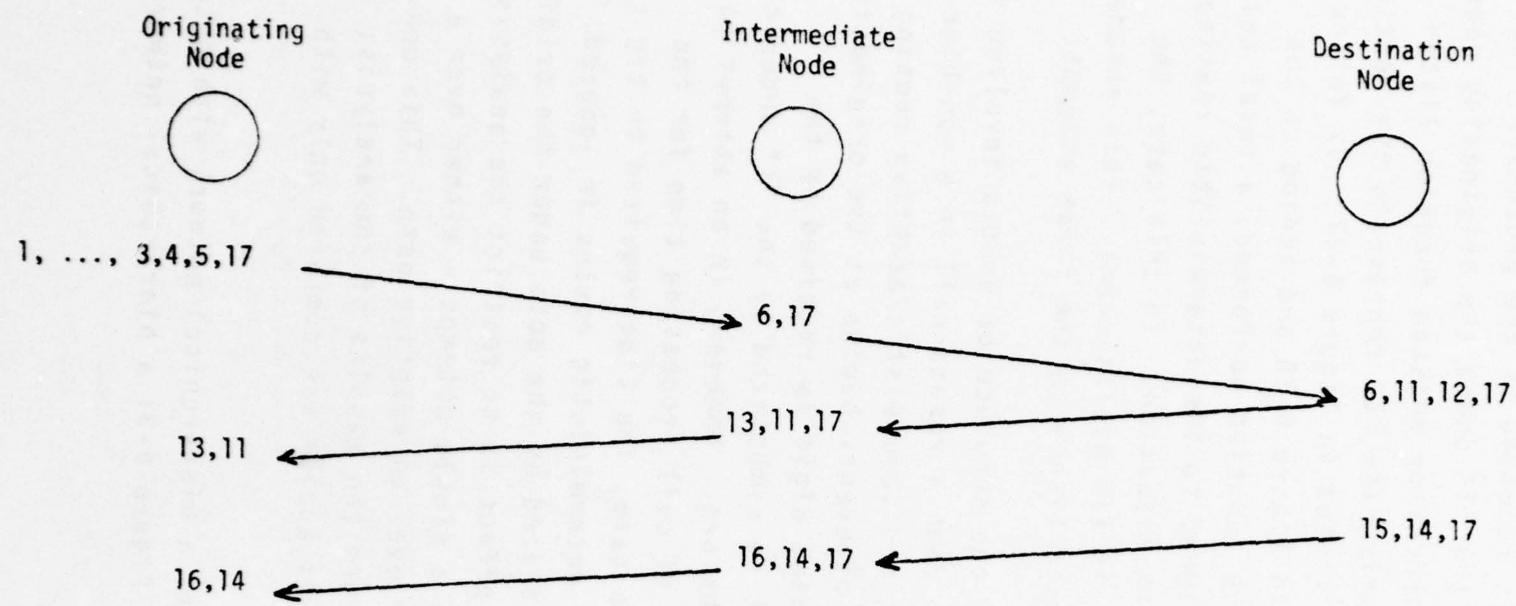
DET (NON-HIERARCHICAL NETWORK)

Figure 6-28

The sequence of events begins at the originating node when the last dialed digit is received by the processor. This event is symbolized by the "1" under the originating node; the "1" refers to the processor related function listed in Figure 6-27. Similarly, the "2" represents the routing table look-up function listed in Figure 6-27. By following the flow depicted in Figure 6-28 and adding up the times estimated for each function performed, a total call set-up time can be assigned to the deterministic routing, non-hierarchical network situation. In this case, the total call set-up time is 176 milliseconds. This assumes that a connection is established on the first attempt.

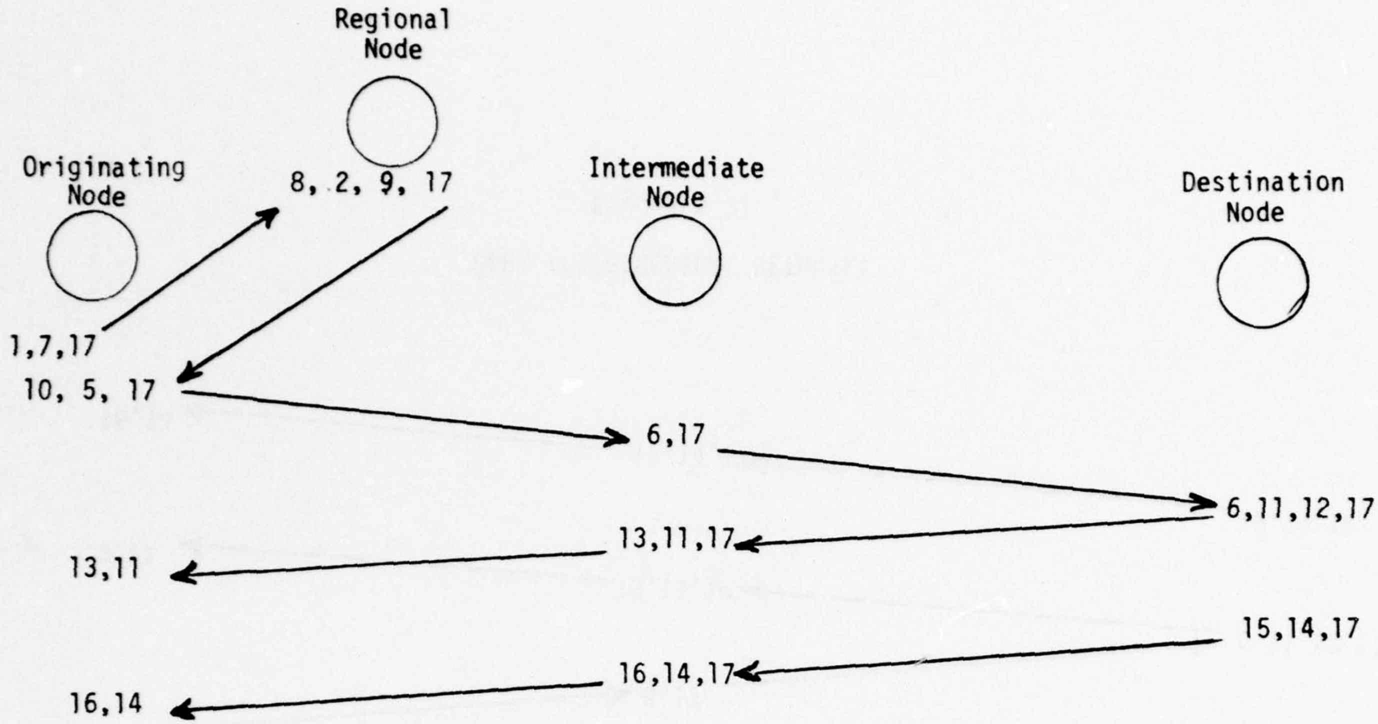
Figure 6-29 represents the sequence of events involved in setting up and tearing down a remote call in a non-hierarchical network using a deterministic/adaptive routing scheme. The sequence of events begins at the originating node when the last dialed digit is received by the processor. This event is symbolized by the "1" under the originating node, as before. However, in an attempt to normalize the measure of call processing time for the deterministic/adaptive case, the time required to try the primary and secondary deterministic routes is ignored. This omission is symbolized by the dots under the originating node. The net effect is to restrict the analysis to calls completed in a single attempt - either over a deterministic path or over an adaptive path. This constraint does not obscure the results of the analysis; rather, it insures that apples are compared only with apples.

Figure 6-30 represents a hierarchical network with deterministic routing and Figure 6-31 a hierarchical network



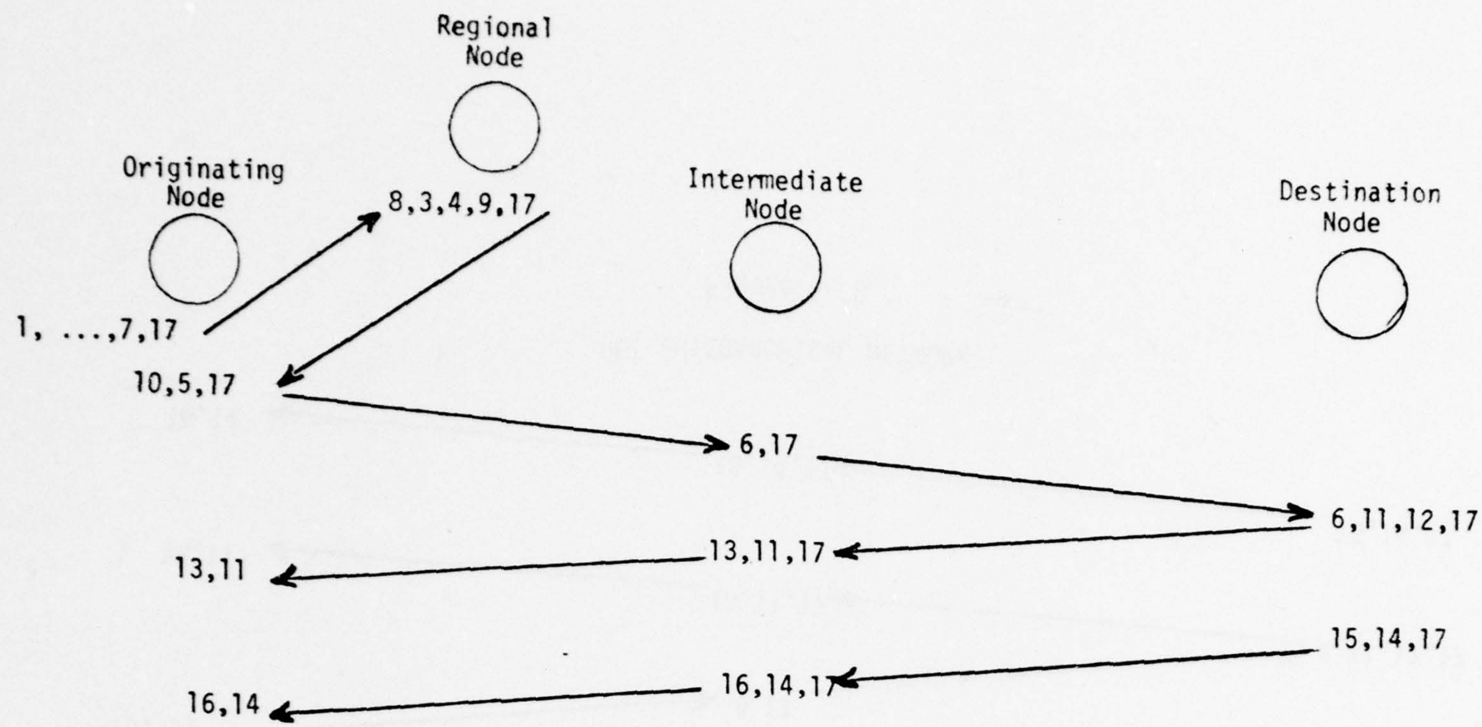
DART (NON-HIERARCHICAL NETWORK)

Figure 6-29



DET (HIERARCHICAL NETWORK)

Figure 6-30



DART (HIERARCHICAL NETWORK)

Figure 6-31

with deterministic/adaptive routing. A comparison of the results obtained from the analysis of call processing times in these four situations is presented in Figure 6-32. Note that the call breakdown time is the same for each of the four cases.

6.2.5 CONCLUSIONS

The implications of the analysis of memory requirements presented above are rather straightforward. Memory size is determined by two distinct factors. Storage required for tables is a nearly linear function of the number of lines terminated by the circuit switch. The table storage required to implement the DART routing scheme is only slightly greater (1350 bytes) than that required for the deterministic routing scheme.

Program storage requirements remain fixed with respect to a specified set of features regardless of circuit switch capacity, over the range of sizes considered in the analysis. The implementation of DART requires approximately 9500 bytes more memory storage than the deterministic algorithm. This is more significant than the differential table storage required for DART. Taken together, both program and tables account for a 10,850 byte additional memory requirement for DART when compared to the deterministic routing scheme.

In terms of call processing times, the implications of the analysis are seemingly unambiguous: in every situation, the deterministic routing algorithm is faster than DART. But this conclusion can be misleading. Neglecting the effects of queueing delays (which may be significant), both DET and DART take less than 1 second to establish a

COMPARISON OF CALL PROCESSING TIMES
FOR CANDIDATE ROUTING ALGORITHMS

FIGURE 6-32

		NON-HIERARCHICAL	HIERARCHICAL
DET	Connect	176 msec	248 msec
	Disconnect	79 msec	79 msec
	Total	255 msec	327 msec
DART	Connect	625 msec	697 msec
	Disconnect	79 msec	79 msec
	Total	704 msec	776 msec

connection across 3 nodes in both non-hierarchical and hierarchical network situations.

A strong case for either DET or DART can be made depending on the criteria under which the evaluation is made. Within the context of this section, deterministic routing in a non-hierarchical network results in minimal call processing times while deterministic routing in a hierarchical network results in minimum memory size for each capacity circuit switch considered (tributary nodes are 10,850 bytes smaller than regional nodes in this case).

The reasons for this state of affairs can be traced to at least two primary causes. First, DART is the same as deterministic routing for the selection of primary and secondary routes. Thus, the adaptive (calculated) routing program and associated storage are resident in memory even when only the deterministic routing scheme is needed for a particular path selection. Thus, DART contains a significant built-in overhead which is unproductive a large percentage of the time.

Second, DART requires global information concerning network connectivity which is arranged in matrix form. Manipulation of matrices requires processing which is geometrically related to the size of the array. The analysis presented above assumed that the network contained 17 nodes. For larger networks, the amount of processing involved rapidly becomes intolerable.

The analysis presented here is predicated upon a particular processor architecture and a proven technology. The advent of economically practical associative memories, for example, may mitigate the situation by decreasing the

processing involved in large matrix manipulation. Modifications to the adaptive routing algorithm, such as restricting connectivity information to local requirements and distributing path construction responsibility among nodes along the path, can also provide some relief. The assignment of routing tasks to a special purpose microprocessor (similar to the Fast Fourier Transform function in signal processing systems) may prove to be effective.

Based on these considerations, it is difficult to predict the final outcome of the deterministic versus deterministic/adaptive trade-off. However, the scales seem to tip in favor of the deterministic routing algorithm at the present time. It remains to be seen if DART can ultimately be made to compete on the basis of program and memory size and call processing times.

7.0 PROBLEMS ENCOUNTERED

During the design of the simulation model, several problems were encountered pertaining to model development, model implementation and computer utilization. In most cases, the resolution of the problems involved substantial time required by discussions with appropriate personnel and subsequent program debugging.

7.1 COMPUTER UTILIZATION

Originally the simulation was developed for operation on a Univac Series 70 processor using the FLOw SIMulator (FLOSIM) language. This computer selection created two significant problems; a local core limitation of 200K and the utilization of partially supported software package. Since several language errors were discovered in the preliminary stages, a debug cycle was deemed necessary.

These were reported to Univac in hopes of creating a completely useful FLOSIM language. In several extreme cases, solutions could not be easily found, and some verbs and entities had to be eliminated in the program development. The end result was that the memory limits became more critical. (Storage was a typical example of an unavailable entity; facilities had to be used instead.) In an attempt to optimally utilize core, some programming required modifications in order to overlay data regions. This technique optimization and the overlay ideas were justly incorporated in the design of connectivity, directory and information matrices.

A decision to convert to an IBM virtual memory system using GPSS was made. This decision resulted in a time and money cost required to acquaint personnel and modify the coding for the new computer system.

7.2 MODEL DEVELOPMENT

Since the simulation was intended to aid in developing an advanced routing protocol many discussions were required in establishing a viable model. One of the problems requiring resolution was "message responsibility" during the phases of message delivery; it was decided the origination node has responsibility at all times. Another problem dealt with pre-empted packet messages. All packets must terminate at the same responsible destination node before transmission to the tributary; however, the transmission path may vary so long as the responsible origination node was constant.

The most significant problem in model development dealt with the generation of output statistics. Since the program was to be modularized, statistics were to be generated in an off-line program. But due to the dynamic nature of the model this was not possible, and an integration of statistics and network simulator programming was necessary. Accompanying this problem was the definition and tabulation of required results; this necessitated coding to generate the results specified by the Statement of Work and later data gathering in order to provide analysis information.

7.3 MODEL UTILIZATION

The debug state of the Network Simulator caused many complex problems to develop which had never been recognized. The most tedious of the problems occurred with the pre-emption scheme; it had been believed pre-emption could only occur during information transmission. However, it was soon apparent pre-emption during signaling/supervision was possible. Therefore, the pre-emption had to be upgraded and modified to cope with connection request, lockin and disconnect signaling.

The next problem required solution to the queuing theme; should it be FIFO, LIFO, depending upon time of pre-emption, priority or both?

A FIFO scheme based on priority was finally selected for this model.

Another problem with the priority scheme caused a re-evaluation of the reservation-acquisition of trunks. After modifying the routing protocol all trunks were acquired at the same time, but reservations occurred separately. This method was finally eliminated in favor of present reservation and acquisition method.

A final problem dealt with the Network Simulator construction; when is a message entering the node, exiting the node or in transit between nodes? This conflict created some problems since the exact message location to node travel was required in determining the proper pre-emption signaling to be used.

In conclusion, the problems discussed summarize some of the problem areas encountered. They represent a significant portion of the major problems, and to the extent that they were resolved, it is not necessary to discuss here the details of the solution. In each case many hours were spent in discussion, defining and resolving the problem, but the specific modifications since these are incorporated in the program.

8.0 RECOMMENDATIONS FOR FURTHER STUDY

1. An area of concern which requires further analysis is that of determining whether the model is in a transient or a relatively steady state for any start-up traffic stimuli. The conditions were considered on an empirical basis for the program work described. Essentially, the model was allowed to run for some time to allow for start-up transients and traffic distributions over various routes. Although various other empirical solutions appear reasonable (e.g., $n+1^{th}$ run would start with "saved values" from n^{th} run), this is an area of some interest.

2. In order to consider network conditions primarily, node processing and service delays were set at fixed values. It would be desirable to introduce "real world" switch processing delays to develop more insight into expected delays in establishing calls and delivering messages/packets in a network. The APT Telecommunications and/or TRI-TAC Programs might be the source of such nodal data.

3. The effect of satellite/long delay links has not been considered. Since these will be part of future long-haul networks, the alternatives offered by such links as part of characterizing the efficiency of any single routing plan and interconnection plan are areas of interest. In particular, since present satellites offer large bandwidth of high quality performance, they appear as attractive alternatives to terrestrial trunking over tandem nodes. However, their present vulnerability to jamming or interdiction would mean that terrestrial aspects of a common satellite ground network would have to accept redistribution of traffic under emergency conditions.

4. The response of the model to imposed traffic does not necessarily lead to stable conditions until some time (both real and simulated) has elapsed. Since empirically derived stability can be expensive in terms of CPU time, and requires considerable analysis to determine whether a stable state has been reached, it is suggested that this area be studied to:

   a. develop operating guidelines, or
   b. develop either an analytic approach or a quantitative measure to determine stability.

5. The Calculated Path algorithm is useful for either simulation models or for use on an on-line basis at a node or a network management center. However, the present technique is matrix structured, and essentially is based on an NXM matrix. This is time and core consuming as the dimensions of the inter-nodal paths increase. It is suggested that other techniques be analyzed. For example, two candidates might be used of a "folded matrix" using a triangular array, or a directive search built around a table or list structure.

6. Investigation of the effect (and delay) of network management in supplying a calculated path in both hierarchical and non-hierarchical networks is an area of some interest to a network designer.

7. A comparison of TRI-TAC /DIN II and projected DCS signaling/supervision with that developed under ADSS might be useful using the developed model and program.

8. A technique for reducing total CPU run times on the model was suggested in meetings between RADC and RCA. This technique is attractive since it assumes that run "n" can start up with conditions which existed at some selected point (other than the start) in run "n-1". This would use a SAVETAPE, which collects and stores network conditions prior to completion of a run, and then calls up these conditions on the next run. The effect of savings in CPU/model run times should be considered along with the validity of using these "saved" conditions to reflect a "loaded" network in this latest run.

APPENDIX I

ANOMALY STATISTICS

This appendix lists the tables used to accumulate the various statistics in the simulation.

```
***********************************************************************
*
*
*
*                     GLICH SUBROUTINE
*
*
*    THE GLICH SUBROUTINE IS DESIGNED TO COLLECT STATISTICS ON THE
* NUMBER OF ANOMALIES THAT OCCUR DURING THE SIMULATION. THE ANOMALIES
* THAT STATISTICS WILL BE GATHER FOR ARE AS FOLLOWS:
*
*                  1.) SUBSCRIBER BUSY
*
*                  2.) PREEMPTION
*
*                  3.) NO CONNECTION POSSIBLE
*
*                  4.) 3 NACK3
*
*                  5.) NODE BUSY
*
*                  6.) TRUNKS BUSY
*
*
*    THESE ANOMALIES WILL BE BROKEN DOWN TO SHOW HOW MANY OCCURRED ON
* THE FIRST PATH, HOW MANY ON THE SECOND PATH, AND HOW MANY ON THE
* FIRST & SECOND PATH. WHERE NEEDED THE ANOMALIES ARE ALSO BROKEN
* DOWN INTO MESSAGE TYPE GROUPS.
*
*    P61 IS USED FOR THE SUBROUTINE RETURN
*
*
*                  ****** NEEDED INPUT ******
*
*
*    P2   MESSAGE TYPE
*
*    P63  PATH REQUEST COUNTER
*
*    P75  CONNECTION POSSIBLE
*
*
*                  ****** OUTPUT ******
*
*
*    THE OUTPUT OF THIS SUBROUTINE WILL BE EIGHT TABLES. THEY ARE
* TABLES 51 THRU 57. THE FOLLOWING IS A DESCRIPTION OF THE TABLES AND
* THEIR ENTRIES:
*
*
*   TABLE 61 (DELST) P20    LOST & DELIEVERED CALLS
*
*        ENTRY      DESCRIPTION
*
*          1        TOTAL LOST CALLS
*          2        TOTAL DELIEVERED CALLS
*
*
```

```
*   TABLE 62 (LTCL1) P21    LOST CALLS 1ST PATH                                        13824200
*                                                                                      13824300
*        ENTRY      DESCRIPTION                                                        13824400
*                                                                                      13824500
*          1        SUBSCRIBER BUSY (CS)                                               13824600
*          2        PREEMPTION (CS,IPNR)                                               13824700
*          3        NO CONNECTION POSSIBLE                                             13824800
*          4        NODE BUSY       AT OT                                              13824801
*                                                                                      13824900
*                                                                                      13825000
*   TABLE 63 (LTCL2) P21    LOST CALLS 2ND PATH                                        13825100
*                                                                                      13825200
*        ENTRY      DESCRIPTION                                                        13825300
*                                                                                      13825400
*          1        SUBSCRIBER BUSY (CS)                                               13825500
*          2        PREEMPTION (CS,IPNR)                                               13825600
*          3        NO CONNECTION POSSIBLE                                             13825700
*          4        NODE BUSY                                                          13825800
*          5        TRUNKS BUSY                                                        13825900
*                                                                                      13826000
*                                                                                      13826100
*   TABLE 64 (LTCL3) P22    LOST CALLS 1ST & SECOND PATHS                              13826200
*                                                                                      13826300
*        ENTRY      DESCRIPTION                                                        13826400
*                                                                                      13826500
*          1        SUBSCRIBER BUSY (CS)                                               13826600
*          2        PREEMPTION (CS,IPNR)                                               13826700
*          3        NO CONNECTION POSSIBLE                                             13826800
*          4        NODE BUSY                                                          13826900
*          5        TRUNKS BUSY                                                        13827000
*                                                                                      13827100
*                                                                                      13827200
*   TABLE 65 (BLFQ1) P20    BLOCKED CALLS 1ST PATH                                     13827300
*                                                                                      13827400
*        ENTRY      DESCRIPTION                                                        13827500
*                                                                                      13827600
*          1        SUBSCRIBER BUSY (NOT CS)                                           13827700
*          2        PREEMPTION (RPNR,DPNR)                                             13827800
*          3        3 NACKS                                                            13827900
*          4        NODE BUSY                                                          13828000
*          5        TRUNKS BUSY                                                        13828100
*                                                                                      13828200
*                                                                                      13828300
*   TABLE 66 (BLFQ2) P20    BLOCKED CALLS 2ND PATH                                     13828400
*                                                                                      13828500
*        ENTRY      DESCRIPTION                                                        13828600
*                                                                                      13828700
*          1        SUBSCRIBER BUSY (NOT CS)                                           13828800
*          2        PREEMPTION (RPNR,DPNR)                                             13828900
*          3        3 NACKS                                                            13829000
*          4        NODE BUSY                                                          13829001
*          5        TRUNKS BUSY                                                        13829002
*                                                                                      13829100
```

DETM (CONT'D.)

```
*                                                                  13829200   6802
*  TABLE 67 (BLFQ3) P21   BLOCKED CALLS 1ST & 2ND PATHS            13829300   6803
*                                                                  13829400   6804
*       ENTRY      DESCRIPTION                                     13829500   6805
*                                                                  13829600   6806
*         1        SUBSCRIBER BUSY (NOT CS)                        13829700   6807
*         2        PREEMPTION (RPNR,DPNR)                          13829800   6808
*         3        3 NACKS                                         13829900   6809
*         4        NODE BUSY                                       13830000   6810
*         5        TRUNKS BUSY                                     13830100   6811
*                                                                  13830200   6812
*                                                                  13830300   6813
*   TABLE 68 (CMRTM) P23  MSGS RETURNED TO STORE AND 2ND PATH REQS 13830400   6814
*                                                                  13830500   6815
*        ENTRY       DESCRIPTION                                   13830600   6816
*                                                                  13830700   6817
*           1          PACKETS (PNR) RETURNED TO STORE             13830800   6818
*           2          MESSAGES (NR) RETURNED TO STORE             13830900   6819
*           3          REQUESTS FOR SECOND (2ND) PATH              13831000   6820
*                                                                  13831100   6821
*                                                                  13831200   6822
*                                                                  13831300   6823
*   THE FOLLOWING PARAMETERS ARE USED IN GLICH:                    13831400   6824
*                                                                  13831500   6825
*       P20  TABULATE PAR. FOR TABLE DELST, BLFQ1, & BLFQ2         13831600   6826
*                                                                  13831700   6827
*       P21  TABULATE PAR. FOR TABLE LTCL1  LTCL2, & BLFQ3         13831800   6828
*                                                                  13831900   6829
*       P22  TABULATE PAR. FOR TABLE LTCL3                         13832000   6830
*                                                                  13832100   6831
*       P61  SUBROUTINE RETURN                                     13832200   6832
*                                                                  13832300   6833
*                                                                  13832400   6834
*                                                                  13832500   6835
```

```
*     THE GLITCH SUBROUTINE IS DESIGNED TO COLLECT STATISTICS ON THE
*  NUMBER OF ANOMALIES THAT OCCUR DURING THE SIMULATION. THE ANOMALIES
*  THAT STATISTICS WILL BE GATHER FOR ARE AS FOLLOWS:
*
*                        1.) SUBSCRIBER BUSY
*
*                        2.) PREEMPTION
*
*                        3.) NO CONNECTION POSSIBLE
*
*                        4.) 3 NACK3
*
*                        5.) NODE BUSY
*
*                        6.) TRUNKS BUSY
*
*
*     THESE ANOMALIES WILL BE BROKEN DOWN TO SHOW HOW MANY OCCURRED ON
*  THE FIRST PATH, HOW MANY ON THE SECOND PATH, AND HOW MANY ON THE
*  FIRST & SECOND PATH. WHERE NEEDED THE ANOMALIES ARE ALSO BROKEN
*  DOWN INTO MESSAGE TYPE GROUPS.
*
*     P61 IS USED FOR THE SUBROUTINE RETURN
*
*
*                         ****** NEEDED INPUT ******
*
*
*     P2    MESSAGE TYPE
*
*     P63   PATH REQUEST COUNTER
*
*     P75   CONNECTION POSSIBLE
*
*
*                           ****** OUTPUT ******
*
*
*     THE OUTPUT OF THIS SUBROUTINE WILL BE EIGHT TABLES. THEY ARE
*  TABLES 85 THRU 94. THE FOLLOWING IS A DESCRIPTION OF THE TABLES AND
*  THEIR ENTRIES:
*
*
*   TABLE 85 (DELST) P20  TOTAL LOST AND DELIVERED CALLS
*
*          ENTRY     DESCRIPTION
*
*            1         TOTAL LOST CALLS
*            2         TOTAL DELIEVERED CALLS
*
*
*   TABLE 86 (LOST1) P21   LOST CALLS 1ST PATH
*
*          ENTRY     DESCRIPTION
*
*            1         SUBSCRIBER BUSY (CS)
*            2         PREEMPTION (CS,IPNR)
```

```
*         3       NO CONNECTION POSSIBLE                               24825000
*         4       NODE BUSY      AT OT                                 24825001
*                                                                      24825100
*                                                                      24825200
*  TABLE 87 (LOST2) P21    LOST CALLS 2ND PATH                         24825300
*                                                                      24825400
*       ENTRY     DESCRIPTION                                          24825500
*                                                                      24825600
*         1       SUBSCRIBER BUSY                                      24825700
*         2       PREEMPTION (CS,IPNR)                                 24825800
*         3       NO CONNECTION POSSIBLE                               24825900
*                                                                      24826000
*                                                                      24826100
*  TABLE 88 (LOST3) P21    LOST CALLS 3TH PATH                         24826200
*                                                                      24826300
*       ENTRY     DESCRIPTION                                          24826400
*                                                                      24826500
*         1       SUBSCRIBER BUSY (CS)                                 24826600
*         2       PREEMPTION (CS,IPNR)                                 24826700
*         3       NO CONNECTION POSSIBLE                               24826800
*         4       NODE BUSY                                            24826900
*         5       TRUNKS BUSY                                          24827000
*                                                                      24827100
*                                                                      24827200
*  TABLE 89 (LOST4) P22    LOST CALLS 1ST & SECOND & THIRD PATHS       24827300
*                                                                      24827400
*       ENTRY     DESCRIPTION                                          24827500
*                                                                      24827600
*         1       SUBSCRIBER BUSY (CS)                                 24827700
*         2       PREEMPTION (CS,IPNP)                                 24827800
*         3       NO CONNECTION POSSIBLE                               24827900
*         4       NODE BUSY                                            24828000
*         5       TRUNKS BUSY                                          24828100
*                                                                      24828200
*                                                                      24828300
*  TABLE 90 (BLKD1) P20    BLOCKED CALLS 1ST PATH                      24828400
*                                                                      24828500
*       ENTRY     DESCRIPTION                                          24828600
*                                                                      24828700
*         1       SUBSCRIBER BUSY (NOT CS)                             24828800
*         2       PREEMPTION (RPNR,DPNR)                               24828900
*         3       3 NACKS                                              24829000
*         4       NODE BUSY                                            24829100
*         5       TRUNKS BUSY                                          24829200
*                                                                      24829300
*                                                                      24829400
*  TABLE 91 (BLKD2) P20    BLOCKED CALLS SECOND PATH                   24829500
*                                                                      24829600
*       ENTRY     DESCRIPTION                                          24829700
*                                                                      24829800
*         1       SUBSCRIBER BUSY (NOT CS)                             24829900
*         2       PREEMPTION (RPNR,DPNR)                               24830000
*         3       3 NACKS                                              24830100
*         4       NODE BUSY                                            24830200
*         5       TRUNKS BUSY                                          24830300
*                                                                      24830400
*                                                                      24830500
```

```
*    TABLE 92 (BLKD3) P20   BLOCKED CALLS 3TH PATH                                   24830600
*                                                                                    24830700
*          ENTRY      DESCRIPTION                                                    24830800
*                                                                                    24830900
*            1        SUBSCRIBER BUSY (NOT CS)                                       24831000
*            2        PREEMPTION (RPNR,DPNR)                                         24831100
*            3        3 NACKS                                                        24831200
*            4        NODE BUSY                                                      24831201
*            5        TRUNKS BUSY                                                    24831202
*                                                                                    24831300
*                                                                                    24831400
*    TABLE 93 (BLKD4) P21   BLOCKED CALLS 1ST & 2ND & 3TH PATHS                      24831500
*                                                                                    24831600
*          ENTRY      DESCRIPTION                                                    24831700
*                                                                                    24831800
*            1        SUBSCRIBER BUSY (NOT CS)                                       24831900
*            2      \ PREEMPTICN (RPNR,DPNR)                                         24832000
*            3        3 NACKS                                                        24832100
*            4        NODE BUSY                                                      24832200
*            5        TRUNKS BUSY                                                    24832300
*                                                                                    24832400
*                                                                                    24832500
*      TABLE 94 (STR23) P23  MSGS RETURNED TO STORE AND 2ND & 3TH PATH RE24832600
*                                                                                    24832700
*           ENTRY      DESCRIPTION                                                   24832800
*                                                                                    24832900
*             1          PACKETS (PNR) RETURNED TO STORE                             24833000
*             2          MESSAGES (NR) RETURNED TO STORE                             24833100
*             3          REQUESTS FOR SECOND (2ND) PATH                              24833200
*             4          REQUESTS FOR THIRD (3TH) PATH                               24833300
*                                                                                    24833400
*                                                                                    24833500
*                                                                                    24833600
*      THE FOLLOWING PARAMETERS ARE USED IN GLICH:                                   24833700
*                                                                                    24833800
*          P20  TABULATE PAR. FOR TABLE DELST, BLKD1, & BLKD2 & BLKD3                24833900
*                                                                                    24834000
*          P21  TABULATE PAR. FOR TABLE LOST1  LOST2, LOST3, & BLKD4                 24834100
*                                                                                    24834200
*          P22  TABULATE PAR. FOR TABLE LOST4                                        24834300
*                                                                                    24834400
*          P23  TABULATE PAR FOR TABLE STR23                                         24834500
*                                                                                    24834600
*          P61  SUBROUTINE RETURN                                                    24834700
*                                                                                    24834800
```

TABLE DELST

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
2000	1.904	.293	3809.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	191	9.54	9.5	90.4	.525	-3.077
2	1809	90.44	100.0	.0	1.050	.324

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LTCL1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
140	1.399	.520	196.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	86	61.42	61.4	38.5	.714	-.769
2	52	37.14	98.5	1.4	1.428	1.153
3	2	1.42	100.0	.0	2.142	3.076

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LTCL2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
51	3.607	1.078	184.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.277	-2.418
2	5	9.80	9.8	90.1	.554	-1.491
3	28	54.90	64.7	35.2	.831	-.563
4	0	.00	64.7	35.2	1.108	.363
5	18	35.29	100.0	.0	1.385	1.291

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LTCL3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
191	1.989	1.207	380.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	86	45.02	45.0	54.9	.502	-.819
2	57	29.84	74.8	25.1	1.005	.008
3	30	15.70	90.5	9.4	1.507	.837
4	0	.00	90.5	9.4	2.010	1.665
5	18	9.42	100.0	.0	2.513	2.494

REMAINING FREQUENCIES ARE ALL ZERO

LOST CALL TABLES

DETM - HIER (PROGRAM 1)

TABLE BLFQ1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
251	3.350	1.878	841.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	84	33.46	33.4	66.5	.298	-1.251
2	22	8.76	42.2	57.7	.596	-.718
3	6	2.39	44.6	55.3	.895	-.186
4	0	.00	44.6	55.3	1.193	.345
5	139	55.37	100.0	.0	1.492	.877

REMAINING FREQUENCIES ARE ALL ZERO

TABLE BLFQ2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
8	4.625	1.058	37.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.216	-3.424
2	1	12.50	12.5	87.5	.432	-2.479
3	0	.00	12.5	87.5	.648	-1.535
4	0	.00	12.5	87.5	.864	-.590
5	7	87.50	100.0	.0	1.081	.354

REMAINING FREQUENCIES ARE ALL ZERO

TABLE BLFQ3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
259	3.389	1.871	878.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	84	32.43	32.4	67.5	.294	-1.277
2	23	8.88	41.3	58.6	.589	-.742
3	6	2.31	43.6	56.3	.884	-.208
4	0	.00	43.6	56.3	1.179	.326
5	146	56.37	100.0	.0	1.474	.860

REMAINING FREQUENCIES ARE ALL ZERO

TABLE CMRTM

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
399	2.203	.677	879.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	59	14.78	14.7	85.2	.453	-1.776
2	200	50.12	64.9	35.0	.907	-.299
3	140	35.08	100.0	.0	1.361	1.176

REMAINING FREQUENCIES ARE ALL ZERO

BLOCKED CALL TABLES

DETM - HIER (PROGRAM 1)

TABLE DELST

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
2945	1.890	.312	5379.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	311	10.93	10.9	89.0	.528	-2.854
2	2534	89.06	100.0	.0	1.057	.350

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LOST1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
288	1.899	.929	547.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	140	48.61	48.6	51.3	.526	-.967
2	37	12.84	61.4	38.5	1.053	.108
3	111	38.54	100.0	.0	1.579	1.183

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LOST2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
18	2.944	.235	53.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.339	-8.253
2	1	5.55	5.5	94.4	.679	-4.008
3	17	94.44	100.0	.0	1.018	.235

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LOST3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
5	3.799	1.093	19.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.263	-2.559
2	0	.00	.0	100.0	.526	-1.645
3	3	59.99	59.9	40.0	.789	-.731
4	0	.00	59.9	40.0	1.052	.182
5	2	39.99	100.0	.0	1.315	1.097

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LOST4

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
311	1.990	.965	619.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	140	45.01	45.0	54.9	.502	-1.025
2	38	12.21	57.2	42.7	1.004	.009
3	131	42.12	99.3	.6	1.507	1.045
4	0	.00	99.3	.6	2.009	2.081
5	2	.64	100.0	.0	2.512	3.117

REMAINING FREQUENCIES ARE ALL ZERO

LOST CALL TABLES

DART - HIER (PROGRAM 2)

TABLE BLKD1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
208	2.802	1.882	583.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	96	46.15	46.1	53.8	.356	-.957
2	19	9.13	55.2	44.7	.713	-.426
3	8	3.84	59.1	40.8	1.070	.104
4	0	.00	59.1	40.8	1.427	.635
5	85	40.86	100.0	.0	1.783	1.166

REMAINING FREQUENCIES ARE ALL ZERO

TABLE BLKD2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
13	4.769	.832	62.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.209	-4.530
2	1	7.69	7.6	92.3	.419	-3.328
3	0	.00	7.6	92.3	.629	-2.126
4	0	.00	7.6	92.3	.838	-.924
5	12	92.30	100.0	.0	1.048	.277

REMAINING FREQUENCIES ARE ALL ZERO

TABLE BLKD3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
2	5.000	.000	10.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.199	-.000
2	0	.00	.0	100.0	.399	-.000
3	0	.00	.0	100.0	.599	-.000
4	0	.00	.0	100.0	.799	-.000
5	2	100.00	100.0	.0	1.000	-.000

REMAINING FREQUENCIES ARE ALL ZERO

TABLE BLKD4

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
223	2.937	1.894	655.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	96	43.04	43.0	56.9	.340	-1.022
2	20	8.96	52.0	47.9	.680	-.494
3	8	3.58	55.6	44.3	1.021	.033
4	0	.00	55.6	44.3	1.361	.560
5	99	44.39	100.0	.0	1.702	1.088

REMAINING FREQUENCIES ARE ALL ZERO

TABLE STR23

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
326	2.174	.782	709.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	61	18.71	18.7	81.2	.459	-1.501
2	162	49.69	68.4	31.5	.919	-.223
3	88	26.99	95.3	4.6	1.379	1.054
4	15	4.60	100.0	.0	1.839	2.332

REMAINING FREQUENCIES ARE ALL ZERO

BLOCKED CALL TABLES

DART - HIER (PROGRAM 2)

TABLE CELST

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
2423	1.907	.290	4621.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	225	9.28	9.2	90.7	.524	-3.125
2	2198	90.71	100.0	.0	1.048	.319

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LTCL1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
176	1.352	.502	238.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	116	65.90	65.9	34.0	.739	-.701
2	58	32.95	98.8	1.1	1.478	1.289
3	2	1.13	100.0	.0	2.218	3.281

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LTCL2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
49	3.326	1.027	163.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.300	-2.264
2	8	16.32	16.3	83.6	.601	-1.291
3	29	59.18	75.5	24.4	.901	-.317
4	0	.00	75.5	24.4	1.202	.655
5	12	24.48	100.0	.0	1.503	1.628

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LTCL3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
225	1.782	1.042	401.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	116	51.55	51.5	48.4	.561	-.749
2	66	29.33	80.8	19.1	1.122	.208
3	31	13.77	94.6	5.3	1.683	1.167
4	0	.00	94.6	5.3	2.244	2.126
5	12	5.33	100.0	.0	2.805	3.085

REMAINING FREQUENCIES ARE ALL ZERO

LOST CALL TABLES

DET - NON H (PROGRAM 3)

TABLE BLFQ1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
266	3.165	1.890	842.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	98	36.84	36.8	63.1	.315	-1.145
2	28	10.52	47.3	52.6	.631	-.616
3	6	2.25	49.6	50.3	.947	-.087
4	0	.00	49.6	50.3	1.263	.441
5	134	50.37	100.0	.0	1.579	.970

REMAINING FREQUENCIES ARE ALL ZERO

TABLE BLFQ2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
6	4.500	1.222	27.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.222	-2.862
2	1	16.66	16.6	83.3	.444	-2.044
3	0	.00	16.6	83.3	.666	-1.226
4	0	.00	16.6	83.3	.888	-.408
5	5	83.33	100.0	.0	1.111	.408

REMAINING FREQUENCIES ARE ALL ZERO

TABLE BLFQ3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
272	3.194	1.886	869.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	98	36.02	36.0	63.9	.313	-1.163
2	29	10.66	46.6	53.3	.626	-.633
3	6	2.20	48.8	51.1	.939	-.103
4	0	.00	48.8	51.1	1.252	.426
5	139	51.10	100.0	.0	1.565	.956

REMAINING FREQUENCIES ARE ALL ZERO

TABLE CPRTM

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
412	2.203	.659	908.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	56	13.59	13.5	86.4	.453	-1.824
2	216	52.42	66.0	33.9	.907	-.309
3	140	33.98	100.0	.0	1.361	1.206

REMAINING FREQUENCIES ARE ALL ZERO

BLOCKED CALL TABLES

DETM - NON H (PROGRAM 3)

TABLE DELST

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
2793	1.881	.323	5254.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	332	11.88	11.8	88.1	.531	-2.723
2	2461	88.11	100.0	.0	1.063	.367

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LOST1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
300	1.856	.926	557.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	153	50.99	50.9	49.0	.538	-.924
2	37	12.33	63.3	36.6	1.077	.154
3	110	36.66	100.0	.0	1.615	1.233

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LOST2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
21	2.857	.358	60.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.350	-5.181
2	3	14.28	14.2	85.7	.700	-2.391
3	18	85.71	100.0	.0	1.049	.398

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LOST3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
11	3.000	.000	33.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.333	-.000
2	0	.00	.0	100.0	.666	-.000
3	11	100.00	100.0	.0	1.000	-.000

REMAINING FREQUENCIES ARE ALL ZERO

TABLE LOST4

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
332	1.957	.938	650.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	153	46.08	46.0	53.9	.510	-1.020
2	40	12.04	58.1	41.8	1.021	.044
3	139	41.86	100.0	.0	1.532	1.110

REMAINING FREQUENCIES ARE ALL ZERO

LOST CALL TABLES

DART - NON H (PROGRAM 4)

TABLE BLKD1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
215	3.088	1.859	664.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	78	36.27	36.2	63.7	.323	-1.123
2	27	12.55	48.8	51.1	.647	-.585
3	9	4.18	53.0	46.9	.971	-.047
4	0	.00	53.0	46.9	1.295	.490
5	101	46.97	100.0	.0	1.618	1.028

REMAINING FREQUENCIES ARE ALL ZERO

TABLE BLKD2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
17	4.823	.727	82.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	0	.00	.0	100.0	.207	-5.255
2	1	5.88	5.8	94.1	.414	-3.880
3	0	.00	5.8	94.1	.621	-2.506
4	0	.00	5.8	94.1	.829	-1.131
5	16	94.11	100.0	.0	1.036	.242

REMAINING FREQUENCIES ARE ALL ZERO

TABLE BLKD4

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
232	3.215	1.855	746.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	78	33.62	33.6	66.3	.310	-1.194
2	28	12.06	45.6	54.3	.621	-.655
3	9	3.87	49.5	50.4	.932	-.116
4	0	.00	49.5	50.4	1.243	.422
5	117	50.43	100.0	.0	1.554	.961

REMAINING FREQUENCIES ARE ALL ZERO

TABLE STR23

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
358	2.256	.749	808.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
1	50	13.96	13.9	86.0	.443	-1.678
2	182	50.83	64.8	35.1	.886	-.343
3	110	30.72	95.5	4.4	1.329	.991
4	16	4.46	100.0	.0	1.772	2.327

REMAINING FREQUENCIES ARE ALL ZERO

BLOCKED CALL TABLES

DART - NON H (PROGRAM 4)

APPENDIX II
DECISION TABLES

The decision tables used to define each of the routing schemes are contained in this appendix.

The tables are read vertically starting at the top of the column corresponding to a connection request (CR) for the type of message to be handled. At the foot of each column is the number of the succeeding column for handling the message.

QUESTIONS	CR-CS COL. 2 ABA2(N)										CR-IPNR COL. 3 AAA3(N)								CR-RPNR COL. 4 AAA4(N)							
		A	B	C	D	E	F	G	H	I		A	B	C	D	E	F	G		A	B	C	D	E	F	G
1. ORIGINATING NODE																										
2. ORIGINATING TRIBUTARY																										
3. DESTINATION TRIBUTARY	64	N	N	N	Y	Y	Y	Y																		
4. THE RON											32	N	N	N	Y	Y										
5. THE RDN																			16	N	N	N	Y	Y		
6. THE LN																										
7. CS PROTOCOL																										
8. MS PROTOCOL																										
9. PS PROTOCOL																										
10. MULTIPLE DESTINATION																										
11. LAST IN ASSEMBLY SET																										
12. FIRST REQUEST																										
13. SECOND REQUEST																										
14. THIRD REQUEST																										
15. LN CAPABILITY																										
16. LAST PACKET																										
17. ON AND OT																										
18. OT AND RON																										
19. RON AND RDN																										
20. RDN AND DT																										
21. RON AND RDN AND DT																										
22. FIRST NACK																										
23. SECOND NACK																										
24. THIRD NACK																										
25. NODE BUSY	2	N	Y	N	N	Y	N	N			2	N	Y	N	N	Y			2	N	Y	N	N	Y		
26. TRUNKS BUSY	4	N	N	Y							4	N	N	Y	-	-			4	N	N	Y	-	-		
27. SUBSCRIBER BUSY	8				N	-	Y	N																		
28. SECURITY MISMATCH	16				N	-	-	Y																		
29. PREEMPTED																										
30. NEW PATH																										
31. CONNECTION POSSIBLE																										
32. VIRGIN MESSAGE																										
TARGET NO. (N)		1	2	3	4	7	5	6				1	2	3	4	7				1	2	3	4	7		
ACTIONS		A	B	C	D	E	F	G	H	I		A	B	C	D	E	F	G		A	B	C	D	E	F	G
1. CALL ALTERNATE PATH																										
2. INCREMENT PATH REQUEST						X										X								X		
3. DELAY-SECURE SUBSCRIBER								X																		
4. TRANSMIT NEXT PACKET																										
5. DIVIDE PACKETS																										
6. ASSEMBLE PACKETS																										
7. ASSEMBLE CONFERENCE CALLS																										
8. SPLIT TRANSACTION																										
XACTA: NEXT COLUMN																										
: STORE																										
XACTB: INCREMENT PATH																										
: NEXT COLUMN																										
9. TRANSMIT NEXT MESSAGE																										
10. MESSAGE THRUPUT																										
11. MESSAGE NOT DELIVERED																										
12. TERMINATE MSG (COUNT)																										
13. REMOVE A LINK			X	X		X							X	X		X					X	X		X		
14. ASSIGN LN																										
15. INCREMENT PATH					X		X	X							X								X			
16. DECREMENT PATH		X										X								X						
17. DELAY - XN OR P																										
18. NEXT COLUMN		2	6	7	G	8	11	8				3	6	7	8	6				4	6	7	8	6		

DECISION TABLE

-COMMON-

PAGE 1

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QUESTIONS	CS-DPNR COL. 5 AAA5(N)	A	B	C	D	E	F	G	H	I	NODE BUSY COL. 6 AAA6(N)	A	B	C	D	E	F	G	H	I	J
1. ORIGINATING NODE											4	N	Y	Y	N	Y	Y	N	N	Y	
2. ORIGINATING TRIBUTARY																					
3. DESTINATION TRIBUTARY	64	N	N	N	Y	Y	Y	Y													
4. THE RON											32	N	N	Y	N	N	N	Y	-	Y	
5. THE RDN											16	N	N	N	N	Y	N	N	Y	Y	
6. THE LN																					
7. CS PROTOCOL											64	-	N	N	N	N	Y	N	N	N	
8. MS PROTOCOL																					
9. PS PROTOCOL																					
10. MULTIPLE DESTINATION																					
11. LAST IN ASSEMBLY SET																					
12. FIRST REQUEST																					
13. SECOND REQUEST																					
14. THIRD REQUEST																					
15. LN CAPABILITY											2	N	N	Y	Y	N	N	N	N	N	
16. LAST PACKET																					
17. ON AND OT																					
18. OT AND RON																					
19. RON AND RDN																					
20. RDN AND DT																					
21. RON AND RDN AND DT																					
22. FIRST NACK																					
23. SECOND NACK																					
24. THIRD NACK																					
25. NODE BUSY	2	N	Y	N	N	Y	N	N													
26. TRUNKS BUSY	4	N	N	Y																	
27. SUBSCRIBER BUSY	8				N	-	Y	N													
28. SECURITY MISMATCH	16				N	-	-	Y													
29. PREEMPTED																					
30. NEW PATH																					
31. CONNECTION POSSIBLE																					
32. VIRGIN MESSAGE																					

TARGET NO. (N)		1	2	3	4	7	5	6				1	3	3	2	3	4	1	1	3	
ACTIONS		A	B	C	D	E	F	G	H	I		A	B	C	D	E	F	G	H	I	J
1. CALL ALTERNATE PATH																					
2. INCREMENT PATH REQUEST						X							X	X		X	X			X	
3. DELAY-SECURE SUBSCRIBER								X													
4. TRANSMIT NEXT PACKET																					
5. DIVIDE PACKETS																					
6. ASSEMBLE PACKETS																					
7. ASSEMBLE CONFERENCE CALLS																					
8. SPLIT TRANSACTION																					
XACTA: NEXT COLUMN																					
: STORE																					
XACTB: INCREMENT PATH																					
: NEXT COLUMN																					
9. TRANSMIT NEXT MESSAGE																					
10. MESSAGE THRUPUT																					
11. MESSAGE NOT DELIVERED																					
12. TERMINATE MSG (COUNT)																					
13. REMOVE A LINK			X	X		X															
14. ASSIGN LN															X						
15. INCREMENT PATH					X		X	X				X			X			X	X		
16. DECREMENT PATH		X																			
17. DELAY - XH OR P													44	44		44				44	
18. NEXT COLUMN		5	6	7	8	6	11	8				6	1	1	8	1	1	6	6	1	

DECISION TABLE

-COMMON-

PAGE 2

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AD-A047 644 RCA GOVERNMENT COMMUNICATIONS SYSTEMS CAMDEN NJ F/G 17/2
ADVANCED SIGNALING/SUPERVISION AND ROUTING STUDY.(U)
OCT 77 P J BIRD, P P BOEHM, J J GUZY F30602-74-C-0189
UNCLASSIFIED RADC-TR-77-334 NL

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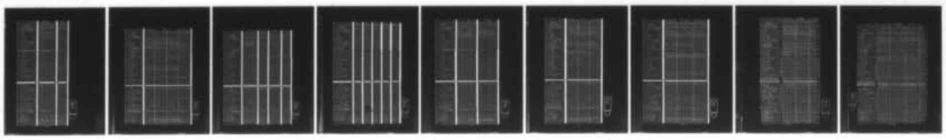

END
DATE
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1 -78
DDC

		TRUNKS BUSY COL 7 AAA7(N)											LOCK-IN COL. 8				
QUESTIONS		A	B	C	D	E	F	G	H	I	J		A	B	C	D	E
1. ORIGINATING NODE	4	N	Y	Y	N	Y	Y	N	N	Y		4	N	Y	-		
2. ORIGINATING TRIBUTARY																	
3. DESTINATION TRIBUTARY																	
4. THE RON	12	N	N	Y	N	N	N	Y	-	Y							
5. THE RDN	16	N	N	N	N	Y	N	N	Y	Y							
6. THE LN																	
7. CS PROTOCOL	4	-	N	N	N	N	Y	N	N	N							
8. MS PROTOCOL																	
9. PS PROTOCOL																	
10. MULTIPLE DESTINATION																	
11. LAST IN ASSEMBLY SET																	
12. FIRST REQUEST																	
13. SECOND REQUEST																	
14. THIRD REQUEST																	
15. LN CAPABILITY	2	N	N	Y	Y	N	N	N	N	N							
16. LAST PACKET																	
17. ON AND OT																	
18. OT AND RON																	
19. RON AND RDN																	
20. RDN AND DT																	
21. RON AND RDN AND DT																	
22. FIRST NACK																	
23. SECOND NACK																	
24. THIRD NACK																	
25. NODE BUSY																	
26. TRUNKS BUSY												-	N	N	Y		
27. SUBSCRIBER BUSY																	
28. SECURITY MISMATCH																	
29. PREEMPTED																	
30. NEW PATH																	
31. CONNECTION POSSIBLE																	
32. VIRGIN MESSAGE																	
TARGET NO. (N)		1	3	3	2	3	4	1	1	3							
ACTIONS		A	B	C	D	E	F	G	H	I	J		A	B	C	D	E
1. CALL ALTERNATE PATH																	
2. INCREMENT PATH REQUEST			X	X		X	X			X							
3. DELAY-SECURE SUBSCRIBER																	
4. TRANSMIT NEXT PACKET																	
5. DIVIDE PACKETS																	
6. ASSEMBLE PACKETS																	
7. ASSEMBLE CONFERENCE CALLS																	
8. SPLIT TRANSACTION															X		
XACTA: NEXT COLUMN															21		
: STORE																	
XACTB: INCREMENT PATH																	
: NEXT COLUMN															7		
9. TRANSMIT NEXT MESSAGE																	
10. MESSAGE THRUPUT																	
11. MESSAGE NOT DELIVERED																	
12. TERMINATE MSG (COUNT)																	
13. REMOVE A LINK															B		
14. ASSIGN LN					X												
15. INCREMENT PATH		X			X			X	X				X				
16. DECREMENT PATH														X	A		
17. DELAY - XH OR P			44	44		44				44							
18. NEXT COLUMN		7	1	1	8	1	1	7	7	1			8	9			

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INFORMATION
COL. 9 AAA9(N)

QUESTIONS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC
1. ORIGINATING NODE																														
2. ORIGINATING TRIBUTARY																														
3. DESTINATION TRIBUTARY	64	N	Y	N	N	Y	N	Y	N	Y	-	N	-	N	-	N	N	N	N	Y	Y	N	N							
4. THE RON	32	N	-	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N							
5. THE RDN	16	N	-	N	Y	Y	Y	Y	N	N	Y	N	Y	N	Y	N	N	Y	Y	Y	Y	N	N							
6. THE LN	2	N	-	N	N	N	N	N	Y	N	N	Y	N	Y	N	Y	N	N	N	N	N	Y	Y							
7. CS PROTOCOL	4	-	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N		Y	Y	N	N		
8. MS PROTOCOL	256	-	N	Y	-	-	Y	Y	Y	-							N	N	N	N	N	N	N		N	N				
9. PS PROTOCOL	512	-	N	N	-	-	N	N	N	-							Y	Y	Y	Y	Y	Y	Y		N	N				
10. MULTIPLE DESTINATION	2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N		Y	Y	Y	Y		
11. LAST IN ASSEMBLY SET	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		N	Y	N	Y		
12. FIRST REQUEST																														
13. SECOND REQUEST																														
14. THIRD REQUEST																														
15. LN CAPABILITY																														
16. LAST PACKET	1																	N	Y	N	Y	N	Y							
17. ON AND OT																														
18. OT AND RON																														
19. RON AND RDN																														
20. RDN AND DT																														
21. RON AND RDN AND DT																														
22. FIRST NACK	1	N	N	N	N	N	N	N	N	-	Y	Y	N	N	N	N	N	N	N	N	N	N	N							
23. SECOND NACK	8	N	N	N	N	N	N	N	N	-	N	N	Y	Y	N	N	N	N	N	N	N	N	N							
24. THIRD NACK	4	N	N	N	N	N	N	N	N	-	N	N	N	N	Y	Y	N	N	N	N	N	N	N							
25. NODE BUSY																														
26. TRUNKS BUSY																														
27. SUBSCRIBER BUSY																														
28. SECURITY MISMATCH																														
29. PREEMPTED		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N		
30. NEW PATH																														
31. CONNECTION POSSIBLE																														
32. VIRGIN MESSAGE																														

TARGET NO. (N)		1	2	3	4	2	5	6	7	2	8	8	9	9	Ø	Ø	A	B	C	B	D	B	E	F	G	G	G	G		
ACTIONS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC
1. CALL ALTERNATE PATH																														
2. INCREMENT PATH REQUEST																														
3. DELAY-SECURE SUBSCRIBER																														
4. TRANSMIT NEXT PACKET																														
5. DIVIDE PACKETS																	X		X		X									
6. ASSEMBLE PACKETS																														
7. ASSEMBLE CONFERENCE CALLS																									X	X	X	X		
8. SPLIT TRANSACTION				X	X		X		X								X		X				X							
XACTA: NEXT COLUMN				4	5		5		4								4		5				4							
: STORE				X	X		X		X								X		X				X							
XACTB: INCREMENT PATH				X	X		X		X								X		X				X							
: NEXT COLUMN				12	12		13		13								12		13				13							
9. TRANSMIT NEXT MESSAGE																														
10. MESSAGE THRUPUT																														
11. MESSAGE NOT DELIVERED																														
12. TERMINATE MSG (COUNT)																														
13. REMOVE A LINK															X	X														
14. ASSIGN LN																														
15. INCREMENT PATH			X			X		X		X	X	X	X	X	X	X		X		X	X	X		X						
16. DECREMENT PATH		X																												
17. DELAY - XM OR P			P1	P1	P1	P1	P1	P1 46	P1	P1	P77	P77	[illegible]	[illegible]	[illegible]	[illegible]	P1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							
18. NEXT COLUMN		9	12			12		13		12	15	15	16	16	17	17		14		14	13	14		10	9	9	9	9		

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PRIORITY BUMP — COL 10 AAA (N)

QUESTIONS		A	B	C	D	E	F	G	H	I
1. ORIGINATING NODE	1	N	Y	Y	Y	Y	Y	Y		
2. ORIGINATING TRIBUTARY	8		Y	Y	-	N	-	-		
3. DESTINATION TRIBUTARY										
4. THE RON	12		N	N	Y	N	N	Y		
5. THE RDN	16		N	N	N	N	Y	Y		
6. THE LN	2		N	N	N	Y	N	N		
7. CS PROTOCOL	64		Y	N	N	N	N	N		
8. MS PROTOCOL										
9. PS PROTOCOL										
10. MULTIPLE DESTINATION										
11. LAST IN ASSEMBLY SET										
12. FIRST REQUEST										
13. SECOND REQUEST										
14. THIRD REQUEST										
15. LN CAPABILITY										
16. LAST PACKET										
17. OT AND OT										
18. OT AND RON										
19. RON AND RDN										
20. RDN AND DT										
21. RON AND RDN AND DT										
22. FIRST NACK										
23. SECOND NACK										
24. THIRD NACK										
25. NODE BUSY										
26. TRUNKS BUSY										
27. SUBSCRIBER BUSY										
28. SECURITY MISMATCH										
29. PREEMPTED										
30. NEW PATH										
31. CONNECTION POSSIBLE										
32. VIRGIN MESSAGE										
-										
TARGET NO. (N)		1	2	2	3	3	4	4		
ACTIONS		A	B	C	D	E	F	G	H	I
1. CALL ALTERNATE PATH										
2. INCREMENT PATH REQUEST										
3. DELAY-SECURE SUBSCRIBER										
4. TRANSMIT NEXT PACKET										
5. DIVIDE PACKETS										
6. ASSEMBLE PACKETS										
7. ASSEMBLE CONFERENCE CALLS										
8. SPLIT TRANSACTION										
XACTA: NEXT COLUMN					4	4	5	5		
: STORE					X	X	X	X		
XACTB: INCREMENT PATH										
: NEXT COLUMN										
9. TRANSMIT NEXT MESSAGE										
10. MESSAGE THRUPUT										
11. MESSAGE NOT DELIVERED			X	X						
12. TERMINATE MSG (COUNT)			1	1						
13. REMOVE A LINK										
14. ASSIGN LN										
15. INCREMENT PATH		X								
16. DECREMENT PATH										
17. DELAY - XH OR P										
18. NEXT COLUMN		10								

SUB BUSY — COL 11 AAB(N)

QUESTIONS		A	B	C	D	E
2. ORIGINATING TRIBUTARY	8	N	Y	N		
5. THE RDN	16	N	N	Y		
7. CS PROTOCOL	4	-	-	N		
TARGET NO. (N)		1	2	3		
ACTIONS		A	B	C	D	E
XACTA: NEXT COLUMN				5		
: STORE				X		
11. MESSAGE NOT DELIVERED			X			
12. TERMINATE MSG (COUNT)			1			
15. INCREMENT PATH		X				
18. NEXT COLUMN		11				

DISCONNECT — COL 12 AAC(N)

QUESTIONS		A	B	C	D	E	F	G
1. ORIGINATING NODE		N	Y	Y	Y	Y		
2. ORIGINATING TRIBUTARY	8		Y	Y	N	Y		
5. THE RDN	16		N	N	Y	N		
7. CS PROTOCOL	2		Y	N	N	N		
21. RON AND RDN AND DT	1		-	N	-	Y		
TARGET NO. (N)		1	3	2	4	3		
ACTIONS		A	B	C	D	E	F	G
9. TRANSMIT NEXT MESSAGE					X			
10. MESSAGE THRUPUT			X		X	X		
12. TERMINATE MSG (COUNT)			1	0	1	1		
15. INCREMENT PATH		X						
18. NEXT COLUMN		12						

NACK — COL 13 AAD(N)

QUESTIONS		A	B	C	D	E
1. ORIGINATING NODE	4	N	Y	Y		
20. RDN AND DT	8	-	N	N		
32. VIRGIN MESSAGE	1	-	N	Y		
TARGET NO. (N)		1	2	3		
ACTIONS		A	B	C	D	E
9. TRANSMIT NEXT MESSAGE			X	X		
10. MESSAGE THRUPUT				X		
12. TERMINATE MSG (COUNT)			0	1		
15. INCREMENT PATH		X				
18. NEXT COLUMN		13				

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	PACK COL. 14 AAE(N)					NACK 1 COL. 15 AAF(N)					NACK 2 COL. 16 AAG(N)					NACK 3 COL. 17 AAH(N)					NO. MSG. COL. 18 AAI(N)				
QUESTIONS		A	B	C	D		A	B	C	D		A	B	C	D		A	B	C	D		A	B	C	D
1. ORIGINATING NODE	4	N	Y			4	N	Y			4	N	Y			4	N	Y							
2. ORIGINATING TRIBUTARY																									
3. DESTINATION TRIBUTARY																					8	N	Y		
4. THE RON																									
5. THE RDN																									
6. THE LN																									
7. CS PROTOCOL																									
8. MS PROTOCOL																									
9. PS PROTOCOL																									
10. MULTIPLE DESTINATION																									
11. LAST IN ASSEMBLY SET																									
12. FIRST REQUEST																									
13. SECOND REQUEST																									
14. THIRD REQUEST																									
15. LN CAPABILITY																									
16. LAST PACKET																									
17. ON AND OT																									
18. OT AND RON																									
19. RON AND RDN																									
20. RDN AND DT																									
21. RON AND RDN AND DT																									
22. FIRST NACK																									
23. SECOND NACK																									
24. THIRD NACK																									
25. NODE BUSY																									
26. TRUNKS BUSY																									
27. SUBSCRIBER BUSY																									
28. SECURITY MISMATCH																									
29. PREEMPTED																									
30. NEW PATH																									
31. CONNECTION POSSIBLE																									
32. VIRGIN MESSAGE																									
TARGET NO. (N)			2					2					2					2					2		
ACTIONS		A	B	C	D		A	B	C	D		A	B	C	D		A	B	C	D		A	B	C	D
1. CALL ALTERNATE PATH																									
2. INCREMENT PATH REQUEST																		X							
3. DELAY-SECURE SUBSCRIBER																									
4. TRANSMIT NEXT PACKET			X																						
5. DIVIDE PACKETS																									
6. ASSEMBLE PACKETS																									
7. ASSEMBLE CONFERENCE CALLS																									
8. SPLIT TRANSACTION																									
XACTA: NEXT COLUMN																									
: STORE																									
XACTB: INCREMENT PATH																									
: NEXT COLUMN																									
9. TRANSMIT NEXT MESSAGE																									
10. MESSAGE THRUPUT																									
11. MESSAGE NOT DELIVERED																							X		
12. TERMINATE MSG (COUNT)																							1		
13. REMOVE A LINK																									
14. ASSIGN LN																									
15. INCREMENT PATH		X					X					X					X					X			
16. DECREMENT PATH			X					X					X												
17. DELAY - XH OR P																		44							
18. NEXT COLUMN		14	9				15	9				16	9				17	1				18			

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		RELEASE CHANNEL COL. 20 AAAO(N)												CHANNEL LOST COL. 21 AAK(N)										
QUESTIONS		A	B	C	D	E	F	G	H	I	J	K		A	B	C	D	E	F	G	H	I	J	K
1. ORIGINATING NODE	4	N	N	N	N	N	N	Y	Y	Y														
2. ORIGINATING TRIBUTARY																								
3. DESTINATION TRIBUTARY	64	N	Y	Y	-	-	N	N	N	N			64	N	Y	N	N	N	Y	N	Y	Y		
4. THE RON	32	N	N	-	Y	-	N	N	N	Y			32	N	Y	N	N	Y	N	Y	N	Y		
5. THE RDN	16	N	N	-	-	Y	N	N	Y	N			16	N	N	N	Y	N	N	Y	Y	Y		
6. THE LN	2	N	N	N	N	N	Y	Y	N	N			2	N	N	Y	N	N	N	N	N	N		
7. CS PROTOCOL	1.		Y	N	N	N	N	N	N	N														
8. MS PROTOCOL																								
9. PS PROTOCOL																								
10. MULTIPLE DESTINATION																								
11. LAST IN ASSEMBLY SET																								
12. FIRST REQUEST																								
13. SECOND REQUEST																								
14. THIRD REQUEST																								
15. LN CAPABILITY																								
16. LAST PACKET																								
17. ON AND OT																								
18. OT AND RON																								
19. RON AND RDN																								
20. RDN AND DT																								
21. RON AND RDN AND DT																								
22. FIRST NACK																								
23. SECOND NACK																								
24. THIRD NACK																								
25. NODE BUSY																								
26. TRUNKS BUSY																								
27. SUBSCRIBER BUSY																								
28. SECURITY MISMATCH																								
29. PREEMPTED																								
30. NEW PATH																								
31. CONNECTION POSSIBLE																								
32. VIRGIN MESSAGE																								
TARGET NO. (N)		1	2	2	2	2	2	1	1	1				1	1	2	2	2	2	2	2	2		
ACTIONS		A	B	C	D	E	F	G	H	I	J	K		A	B	C	D	E	F	G	H	I	J	K
1. CALL ALTERNATE PATH																								
2. INCREMENT PATH REQUEST																								
3. DELAY-SECURE SUBSCRIBER																								
4. TRANSMIT NEXT PACKET																								
5. DIVIDE PACKETS																								
6. ASSEMBLE PACKETS																								
7. ASSEMBLE CONFERENCE CALLS																								
8. SPLIT TRANSACTION																								
XACTA: NEXT COLUMN																								
: STORE																								
XACTB: INCREMENT PATH																								
: NEXT COLUMN																								
9. TRANSMIT NEXT MESSAGE																								
10. MESSAGE THRUPUT																								
11. MESSAGE NOT DELIVERED																								
12. TERMINATE MSG (COUNT)			0	0	0	0	0																	
13. REMOVE A LINK																								
14. ASSIGN LN																								
15. INCREMENT PATH																								
16. DECREMENT PATH		X						X	X	X				X	X									
17. DELAY - XH OR P																X	X	X	X	X	X	X		
18. NEXT COLUMN		20						20	20	20				21	21	10	10	10	10	10	10	10		

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COL I AAAI(N)

QUESTIONS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1. ORIGINATING NODE																				
2. ORIGINATING TRIBUTARY	8	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	-			N	N	Y	Y		
3. DESTINATION TRIBUTARY	64	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y	Y		
4. THE RON	32	N	N	N	N	N	N	Y	Y	Y	Y	Y			N	N	N	N		
5. THE RDN	16	N	N	N	N	N	N	N	Y	Y	N	N	Y	Y	N	N	N	N		
6. THE LN	2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N		
7. CS PROTOCOL	4	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	N		
8. MS PROTOCOL																				
9. PS PROTOCOL																				
10. MULTIPLE DESTINATION																				
11. LAST IN ASSEMBLY SET																				
12. FIRST REQUEST	128	Y	N	N	Y	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y		
13. SECOND REQUEST	256	N	Y	N	N	Y	N	N	N	N	Y	N	Y	N	Y	N	N	N		
14. THIRD REQUEST	512	N	N	Y	N	N	Y	N	N	N	N	Y	N	Y	N	Y	N	N		
15. LN CAPABILITY																				
16. LAST PACKET																				
17. ON AND OT	1024	N	N	N	N	N	N	Y	Y	Y										
18. OT AND RON	2048	N	N	N				N	Y	Y	N	N			N	N				
19. RON AND RDN	1	N	N	N					N	Y			N	N						
20. RDN AND DT																				
21. RON AND RDN AND DT																				
22. FIRST NACK																				
23. SECOND NACK																				
24. THIRD NACK																				
25. NODE BUSY																				
26. TRUNKS BUSY																				
27. SUBSCRIBER BUSY																				
28. SECURITY MISMATCH																				
29. PREEMPTED																				
30. NEW PATH																				
31. CONNECTION POSSIBLE																				
32. VIRGIN MESSAGE																				

TARGET NO. (N)		1	2	3	1	2	3	1	1	5	2	4	2	6	2	4	7	7		
ACTIONS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1. CALL ALTERNATE PATH			X			X					X		X		X					
2. INCREMENT PATH REQUEST																				
3. DELAY-SECURE SUBSCRIBER																				
4. TRANSMIT NEXT PACKET																				
5. DIVIDE PACKETS																				
6. ASSEMBLE PACKETS																				
7. ASSEMBLE CONFERENCE CALLS																				
8. SPLIT TRANSACTION																				
XACTA: NEXT COLUMN												4		5		4				
: STORE												X		X		X				
XACTB: INCREMENT PATH																				
: NEXT COLUMN																				
9. TRANSMIT NEXT MESSAGE										X										
10. MESSAGE THRUPUT										X							X	X		
11. MESSAGE NOT DELIVERED				X			X													
12. TERMINATE MSG (COUNT)				1			1			1							1	1		
13. REMOVE A LINK																				
14. ASSIGN LN																				
15. INCREMENT PATH																				
16. DECREMENT PATH																				
17. DELAY - XH OR P										P1		44		44		44	P1	P1		
18. NEXT COLUMN		19	19		19	19		19	19		19		19	5	19					

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PATH AVAILABILITY
COL. 19 AAJ(N)

QUESTIONS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1. ORIGINATING NODE																										
2. ORIGINATING TRIBUTARY	8	Y	Y	Y	N	-	N	-	-	N	N	N	N	-	N	-	N	Y	Y	Y	Y	Y	Y	Y		
3. DESTINATION TRIBUTARY																										
4. THE RON	32	N	N	N	Y	Y	Y	-	-	-	-	-	-	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y		
5. THE RDN	16	N	N	N	N	N	N	Y	Y	Y	-	-	-	N	N	Y	Y	N	N	Y	N	N	Y	N		
6. THE LN	2	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N		
7. CS PROTOCOL	64	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N		
8. MS PROTOCOL																										
9. PS PROTOCOL																										
10. MULTIPLE DESTINATION																										
11. LAST IN ASSEMBLY SET																										
12. FIRST REQUEST	512	-	-	-	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	-	-	-	-	-	-	N		
13. SECOND REQUEST	1024	-	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	-	-	-	-	-	-	Y		
14. THIRD REQUEST																										
15. LN CAPABILITY																										
16. LAST PACKET																										
17. ON AND OT																										
18. OT AND RON	128	N	N	N	-	-	N	-	N	-	-	-	-	-	-	-	-	N	Y	Y	N	Y	Y	-		
19. RON AND RDN	256	N	-	N	N	N	N	N	-	N	N	N	N	N	N	Y	Y	N	N	Y	N	N	Y	N		
20. RDN AND OT		N	N	N	-	-	-	-	N	N	-	-	-	-	-	N	N	-	-	-	-	-	-	-		
21. RON AND RDN AND DT																										
22. FIRST NACK																										
23. SECOND NACK																										
24. THIRD NACK																										
25. NODE BUSY																										
26. TRUNKS BUSY																										
27. SUBSCRIBER BUSY																										
28. SECURITY MISMATCH																										
29. PREEMPTED																										
30. NEW PATH	1	-	N	Y	Y	N	N	Y	N	N	Y	N	N	Y	N	Y	N	N	N	N	N	N	N	Y		
31. CONNECTION POSSIBLE	4	N	Y	Y	Y	Y	N	Y	Y	N	Y	Y	N	Y	N	Y	N	N	N	N	N	N	N	Y		
32. VIRGIN MESSAGE																										

TARGET NO. (N)		1	6	3	4	5	6	7	8	6	Ø	5	6	9	6	7	6	6	6	6	6	6	6	2		
ACTIONS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1. CALL ALTERNATE PATH																										
2. INCREMENT PATH REQUEST																										
3. DELAY-SECURE SUBSCRIBER																										
4. TRANSMIT NEXT PACKET																										
5. DIVIDE PACKETS																								X		
6. ASSEMBLE PACKETS																										
7. ASSEMBLE CONFERENCE CALLS																										
8. SPLIT TRANSACTION																										
XACTA: NEXT COLUMN						4			5			4		4		5										
: STORE						X			X			X		X		X										
XACTB: INCREMENT PATH																										
: NEXT COLUMN																										
9. TRANSMIT NEXT MESSAGE																										
10. MESSAGE THRUPUT																										
11. MESSAGE NOT DELIVERED																										
12. TERMINATE MSG (COUNT)																										
13. REMOVE A LINK																										
14. ASSIGN LN																										
15. INCREMENT PATH																										
16. DECREMENT PATH																										
17. DELAY - XH OR P						44			44			44		44		44										
18. NEXT COLUMN		2	18	3	4		18	5		18	4		18		18		18	18	18	18	18	18	18	4		

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NEW PATH
COL. 1 AAAI(N)

QUESTIONS			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1. ORIGINATING NODE																					
2. ORIGINATING TRIBUTARY		8	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	-			N	N	Y	Y		
3. DESTINATION TRIBUTARY		64	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y	Y		
4. THE RON		32	N	N	N	N	N	Y	Y	Y	Y	Y	Y			N	N	N	N		
5. THE RDN		16	N	N	N	N	N	N	N	Y	Y	N	N	Y	Y	N	N	N	N		
6. THE LN		2	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N		
7. CS PROTOCOL		4	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	N		
8. MS PROTOCOL																					
9. PS PROTOCOL																					
10. MULTIPLE DESTINATION																					
11. LAST IN ASSEMBLY SET																					
12. FIRST REQUEST	1	28	Y	N	N	Y	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y		
13. THIRD REQUEST																					
14. FOURTH REQUEST	5	12	N	N	Y	N	N	Y	N	N	N	N	Y	N	Y	N	Y	N	N		
15. LN CAPABILITY																					
16. LAST PACKET																					
17. ON AND OT	10	24	N	N	N	N	N	N	Y	Y	Y										
18. OT AND RON	20	48	N	N	N				N	Y	Y	N	N			N	N				
19. RON AND RON		1	N	N	N					N	Y			N	N						
20. RON AND DT																					
21. RON AND RON AND DT																					
22. FIRST NACK																					
23. SECOND NACK																					
24. THIRD NACK																					
25. NODE BUSY																					
26. TRUNKS BUSY																					
27. SUBSCRIBER BUSY																					
28. SECURITY MISMATCH																					
29. PREEMPTED																					
30. NEW PATH																					
31. CONNECTION POSSIBLE																					
32. VIRGIN MESSAGE																					
33. SECOND OR THIRD REQUEST	2	56	N	Y	N	N	Y	N	N	N	N	Y	N	Y	N	Y	N	N	N		
34. FIRST OR SECOND REQUEST																					

TARGET NO. (N)			1	2	3	1	2	3	1	1	5	2	4	2	6	2	4	7	7		
ACTIONS			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1. CALL SOPTH PATH				X			X					X		X		X					
2. INCREMENT PATH REQUEST																					
3. DELAY-SECURE SUBSCRIBER																					
4. TRANSMIT NEXT PACKET																					
5. DIVIDE PACKETS																					
6. ASSEMBLE PACKETS																					
7. ASSEMBLE CONFERENCE CALLS																					
8. SPLIT TRANSACTION																					
XACTA: NEXT COLUMN													4		5		4				
: STORE													X		X		X				
XACTB: INCREMENT PATH																					
: NEXT COLUMN																					
9. TRANSMIT NEXT MESSAGE											X										
10. MESSAGE THRUPUT											X							X	X		
11. MESSAGE NOT DELIVERED					X			X													
12. TERMINATE MSG (COUNT)					1			1			1							1	1		
13. REMOVE A LINK																					
14. ASSIGN LN																					
15. INCREMENT PATH																					
16. DECREMENT PATH																					
17. DELAY-XH OR P											P1		44		44		44	P1	P1		
18. NEXT COLUMN			19	19		19	19		19	19				19	5	19					

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PATH AVAILABILITY
COL. 19 AAJ(N)

QUESTIONS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD
1. ORIGINATING NODE																															
2. ORIGINATING TRIBUTARY	8	Y	Y	Y	N	-	N	-	-	N	N	N	N	-	N	-	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	-	N		
3. DESTINATION TRIBUTARY																															
4. THE RON	32	N	N	N	Y	Y	Y	-	-	-	-	-	-	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	N	Y	-	N		
5. THE RDN	16	N	N	N	N	N	N	Y	Y	Y	-	-	-	N	N	Y	Y	N	N	Y	N	N	Y	N	N	N	N	Y	N		
6. THE LN	2	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y		
7. CS PROTOCOL	64	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	Y	N	N	N		
8. MS PROTOCOL																															
9. PS PROTOCOL																															
10. MULTIPLE DESTINATION																															
11. LAST IN ASSEMBLY SET																															
12. FIRST REQUEST																															
13. THIRD REQUEST	1024	-	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	-	-	-	-	-	-	Y	N	-	N	N	N		
14. FOURTH REQUEST																															
15. LN CAPABILITY																															
16. LAST PACKET																															
17. ON AND OT																															
18. OT AND RON	128	N	N	N	-	-	N	-	N	-	-	-	-	-	-	-	-	N	Y	Y	N	Y	Y	-	N	N	-	-	-		
19. RON AND RDN	256	N	-	N	N	N	N	N	-	N	N	N	N	N	N	Y	Y	N	N	Y	N	N	Y	N	N	N	N	-	N		
20. RON AND DT		N	N	N	-	-	-	-	N	N	-	-	-	-	-	N	N	-	-	-	-	-	-	-	-	N		N			
21. RON AND RON AND DT																															
22. FIRST NACK																															
23. SECOND NACK																															
24. THIRD NACK																															
25. NODE BUSY																															
26. TRUNKS BUSY																															
27. SUBSCRIBER BUSY																															
28. SECURITY MISMATCH																															
29. PREEMPTED																															
30. NEW PATH	1	Y	N	Y	Y	N	N	Y	N	N	Y	N	N	Y	N	Y	N	N	N	N	N	N	N	Y	N	N	N	N	N		
31. CONNECTION POSSIBLE	4	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	N	Y	N	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y		
32. VIRGIN MESSAGE																															
33. SECOND OR THIRD REQUEST																															
34. FIRST OR SECOND REQUEST	512	-	-	-	N	N	N	[illegible]	[illegible]	[illegible]	N	[illegible]	[illegible]	Y	Y	Y	Y	-	-	-	-	-	-	-	Y	-	Y	Y	Y		

TARGET NO. (N)		10	6	3	4	5	6	7	8	6	0	5	6	9	6	7	6	6	6	6	6	6	6	2	6	6	5	5	5		
ACTIONS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD
1. CALL SDPTH PATH																															
2. INCREMENT PATH REQUEST																															
3. DELAY-SECURE SUBSCRIBER																															
4. TRANSMIT NEXT PACKET																															
5. DIVIDE PACKETS																								X							
6. ASSEMBLE PACKETS																															
7. ASSEMBLE CONFERENCE CALLS																															
8. SPLIT TRANSACTION																															
XACTA: NEXT COLUMN						4			5			4		4		5											4	5	4		
: STORE						X			X			X		X		X											X	X	X		
XACTB: INCREMENT PATH																															
: NEXT COLUMN																															
9. TRANSMIT NEXT MESSAGE																															
10. MESSAGE THRUPUT																															
11. MESSAGE NOT DELIVERED																															
12. TERMINATE MSG (COUNT)																															
13. REMOVE A LINK																															
14. ASSIGN LN																															
15. INCREMENT PATH																															
16. DECREMENT PATH																															
17. DELAY - XH OR P						44			44			44		44		44											44	44	44		
18. NEXT COLUMN		2	18	3	4		18	5	18	4			18		18		18	18	18	18	18	18	18		18	18					

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